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TECHNICAL REPORT ARLCD-CR-83045

M577 MODULAR SETBACK PIN COMPUTER SIMULATION AND AUTOMATED ASSEMBLY AND TESTING

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MARCH 1984

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LARGE CALIBER WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY

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18. SUPPLEMENTARY NOTES

The initial development of the modular setback pin was conducted by Hamilton Technology, Inc., under contract number DAAK10-77-C-0152 (CPFF).

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

M577 fuze
Modular setback pin
MSP computer simulation
MSP automated assembly and testing equipment
Die cast MSP

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this project was to conduct a computer simulation of the modular setback pin (MSP) motion under setback. The simulation relates time to function, setback magnitude, and nine MSP design features. A second objective was to evaluate possible methods of automating the assembly and testing of the MSP. A history of previous ballistic testing and design changes is also included.

CONTENTS

FIGURES

INTRODUCTION

The modular setback pin (MSP) was designed to operate in both the timer and trigger of the M577 mechanical time fuze. The device senses all standard gun firing environments and differentiates between them and handling shocks, including drops of 40 feet and higher. Further, the unit locks in the functioned position (down) after the setback pulse ceases. This prohibits the setback pin from interfering with the operation of the spin detent. Three parts make up the module as shown in fig. 1: two state-of-the-art zinc die castings and a coil spring. Due to the setback module's extremely small size, it may be applied to a variety of other artillery fuzes, taking advantage of its unique operating features. The complete drawings are shown in Appendix A. Also included in Appendix A are additional drawing changes required to accommodate the MSP. Parts required to be modified include the timer spin detent, all timer plates and the trigger spacer.

The primary functional feature of the setback pin is the Z-shaped groove in its side. The groove continues circumferentially around to the far side of the pin, then extends straight down to the bottom of the pin. There is a slot in the top of the pin to allow a screwdriver-type tool to rotate the pin. This pin is hollow to allow the spring to ride inside it.

The main functional feature of the housing is the diamond-shaped cam on its inside surface. Extending upward from the bottom of the housing is a spring support pin which acts as a guide to keep the spring from buckling. There is a section of the mounting flange removed in order to allow the module to be mounted as close to the outside of the M577 timer as possible. There are also two flats on opposite sides of the flange to enable the module to be constrained from rotating by a mating geometry in the plates in which the setback module is mounted. This is shown in figure 2.

The module is assembled by placing one end of the spring in the setback pin and the other end over the spring support pin of the housing. The vertical section of the pin groove is then positioned over the housing cam and the pin is slid into the housing fully. After this operation the pin is rotated one-half turn, this engages the cam with the zig-zag section of the groove as is shown in fig. 3. The pin can then be compressed. As the pin is compressed, it oscillates rotationally.

A computer-aided study to determine the time required for the MSP to function under various setback loads is described in this report. A modified version of this program determined the relative importance of nine design features as they relate to drop height. Limited physical testing was also conducted. A study and conceptual layout of automated assembly and testing equipment for the MSP are also described.

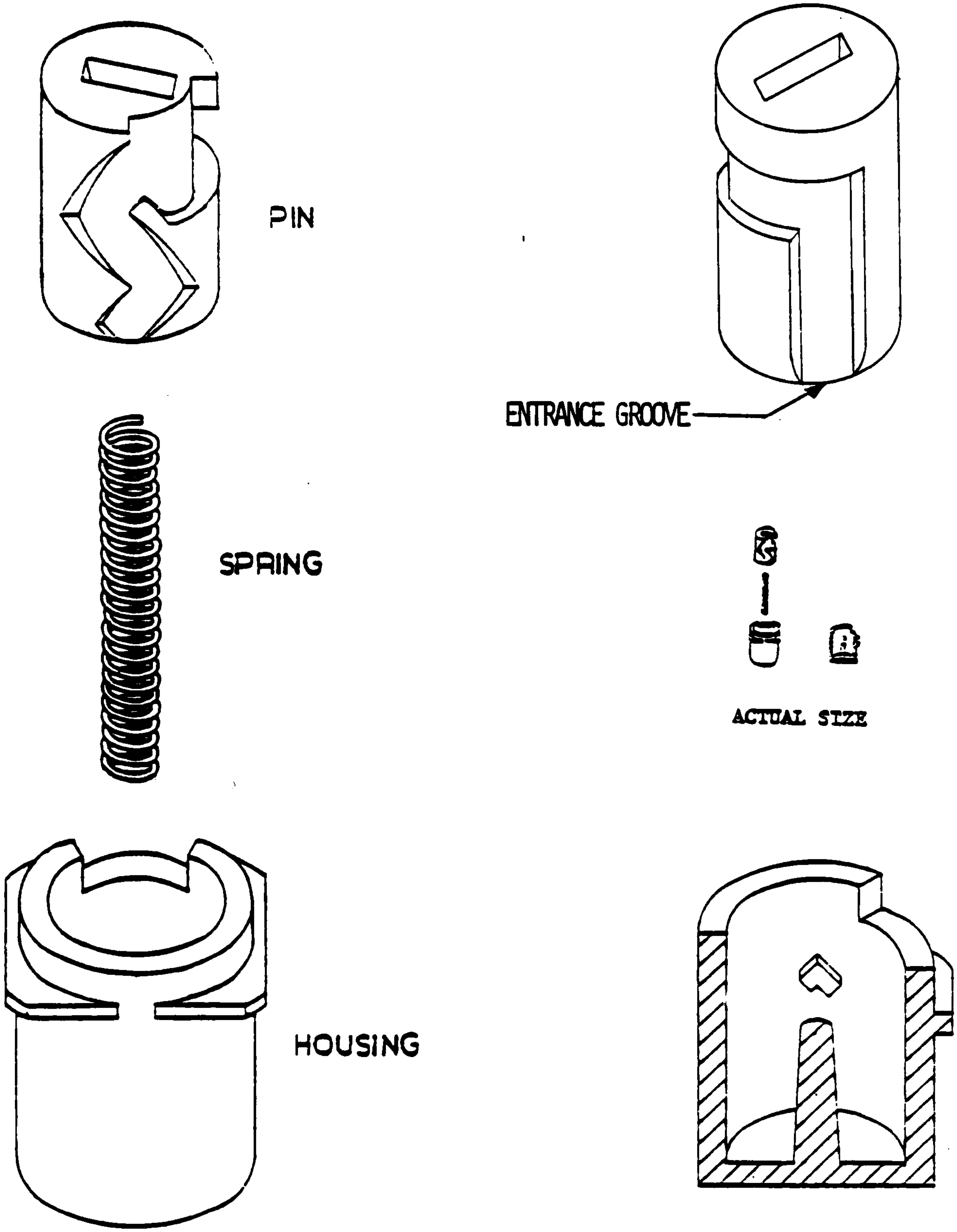


FIGURE 1

EXPLODED VIEW

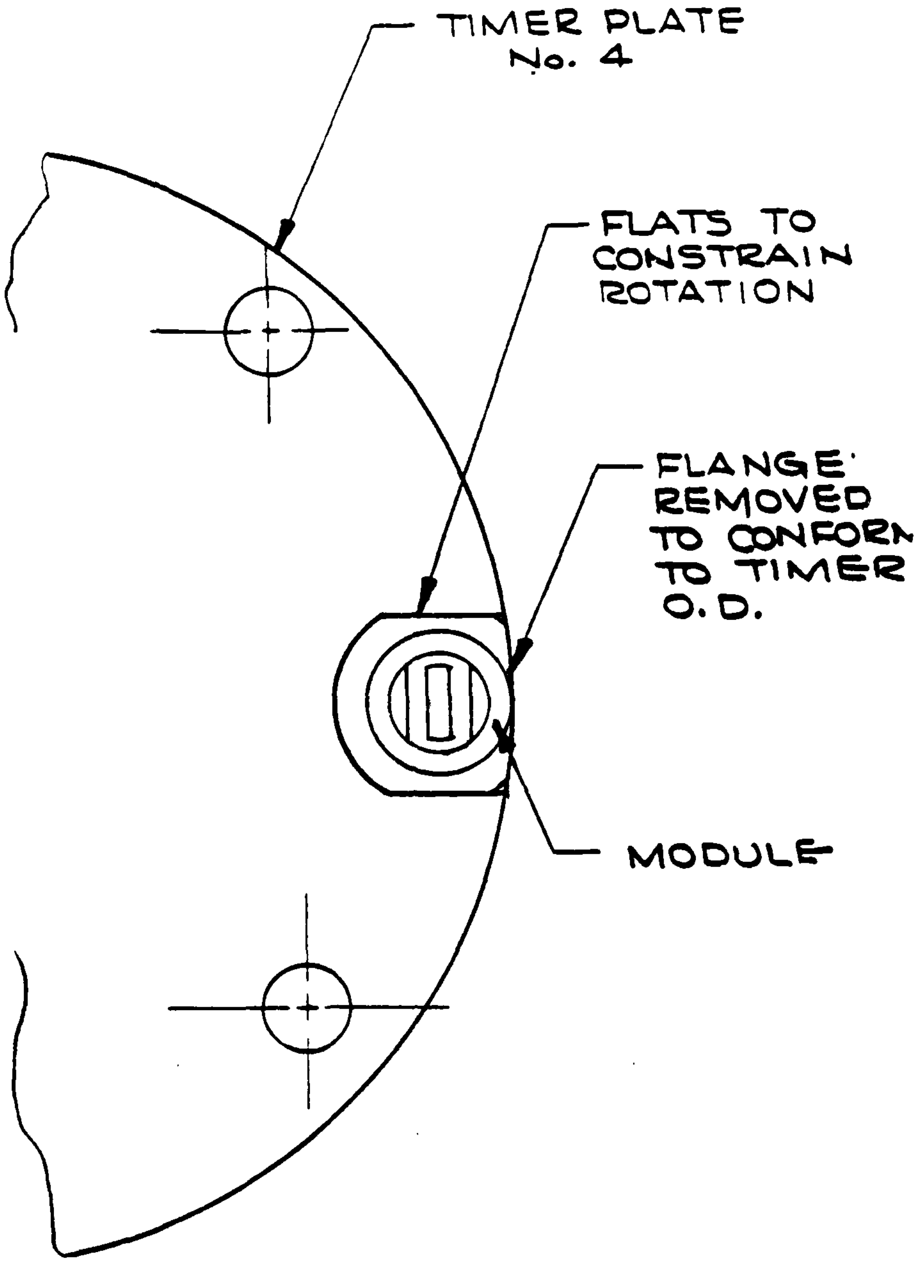
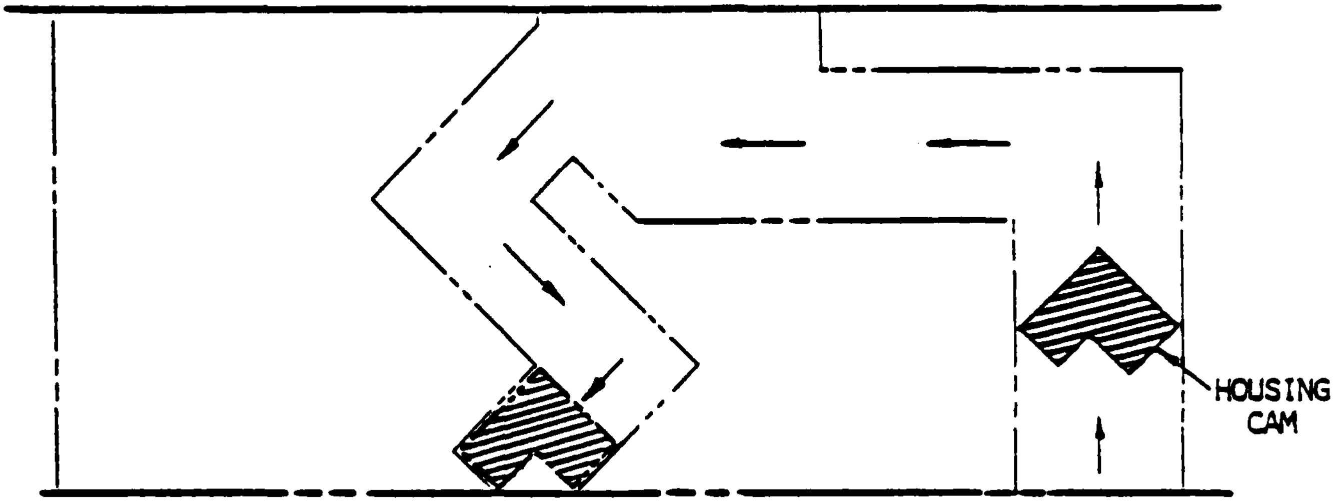


FIGURE 2

NO. 4 PLATE MATING GEOMETRY



CAM PATH

FIGURE 3
ASSEMBLY PROCEDURE

OPERATION

The unique operating feature of the modular setback pin is the rotational oscillation it exhibits while being compressed. Because of this, the MSP functions as a crude runaway escapement, integrating setback and time. As the setback pin is compressed, the housing cam encounters sharp changes in the direction of the pin groove (see fig. 3). Each time the pin groove changes direction, the pin which, of course, is turning in the same direction as the groove, must stop momentarily before turning in the new direction. The pin must then be re-accelerated to continue its travel down the groove. This is analogous to the motion of the balance (sometimes called the lever) in a runaway escapement. Because the pin does actually stop, the kinetic energy it has when it reaches the end of a leg of the track is expended upon impact of the corner. Therefore, energy must be resupplied to continue motion. This energy is supplied by the setback force. Should the setback force not be present, the pin, instead of continuing to compress, will be returned by its spring to the safe position. Herein lies the key to the pin's ability to differentiate between the setback forces of gun-firing and the forces from handling shocks. Handling shocks have too short a duration to re-accelerate the pin at the beginning of the second and third legs of the Z-groove. A standard setback pin would compress regardless of the duration, as long as the setback force was great enough. Whereas, the MSP must "sense" a combination of setback and duration in order for it to arm.

An additional feature of the modular setback pin is its ability to lock down in the functioned position. When the setback pin is completely compressed, it is designed to come to rest directly under a notch in the housing which will catch the pin after cessation of setback (see fig. 4). The MSP will then remain in the down position unless the pin is manually twisted in the counter-clockwise direction. This lockdown feature allows the setback pin to be effectively separated from the spin detent, once it has seen the required setback pulse. Such a feature would also be useful during assembly since many of the testing and assembly operations require that the setback pin be temporarily compressed.

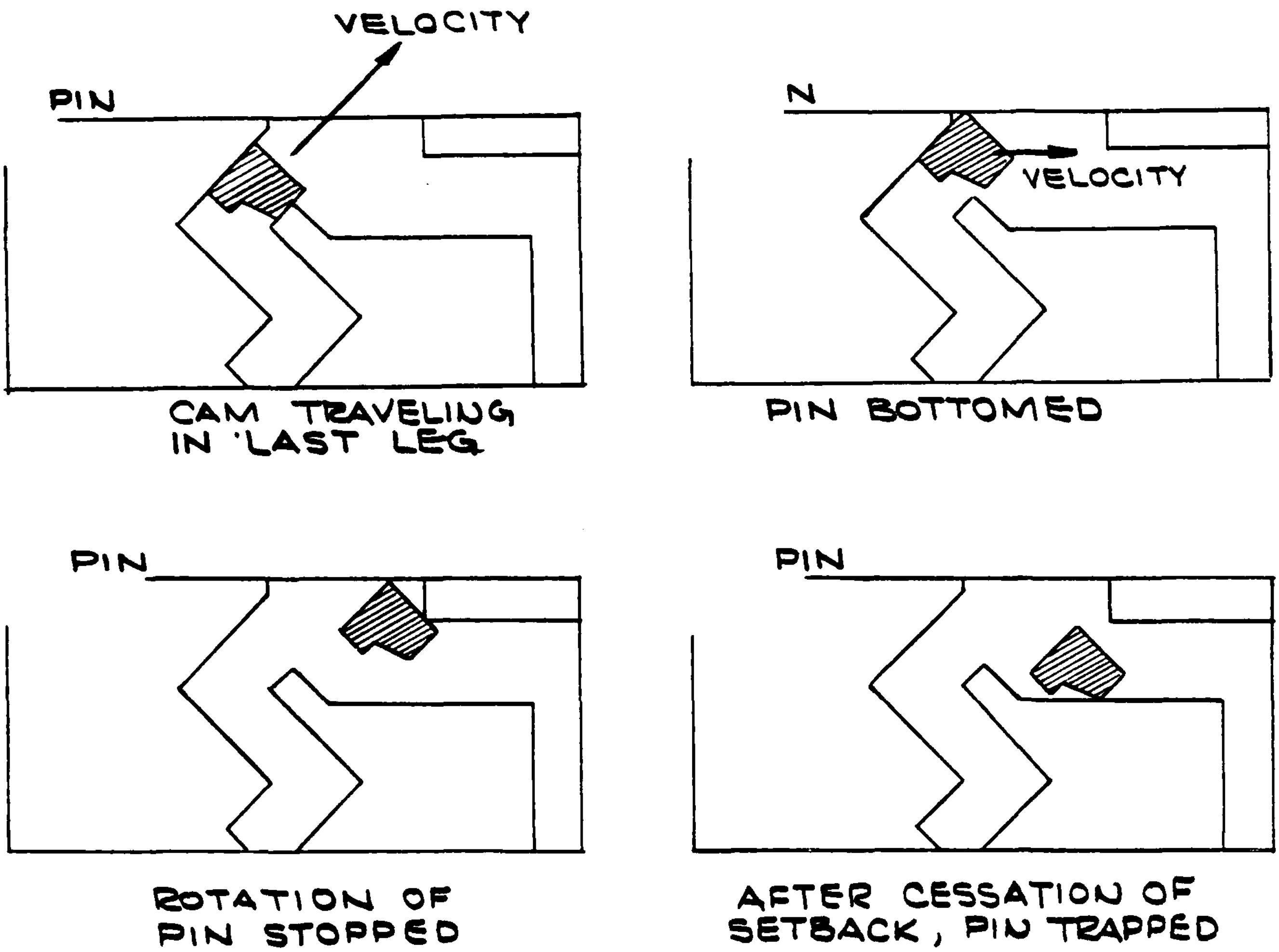


FIGURE 4
LOCK-DOWN FEATURE OF
MODULE

COMPUTER SIMULATION

The equations of motion for the setback pin have been developed by D. L. Overman of Harry Diamond Laboratories and are shown in Appendix B. Due to the complexity of the setback pin motion, certain simplifying assumptions were necessary to reduce the equations of motion to a workable level. These assumptions are as follows:

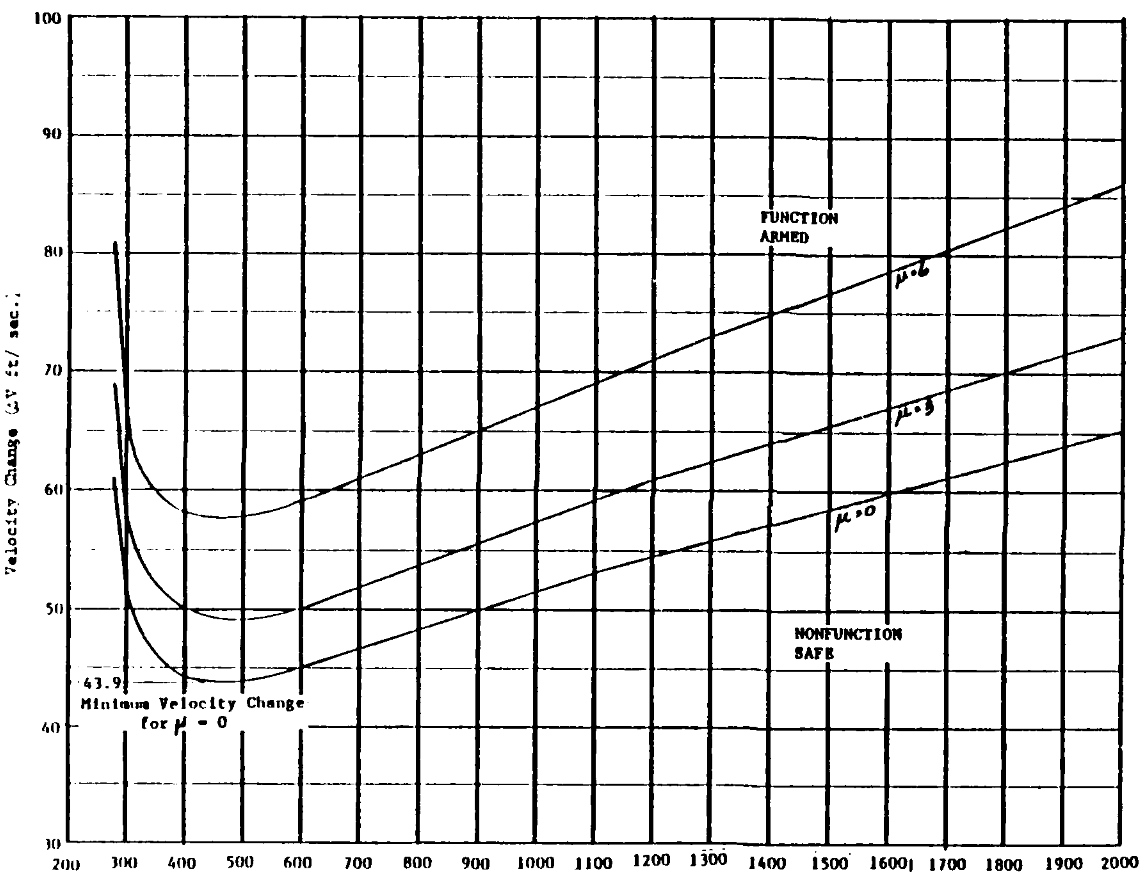
- o Collisions at the end of each stage are completely inelastic.
- o The spring is linear.
- o No friction occurs due to side loads.
- o The setback pulse is rectangular.

The assumption of a rectangular setback pulse provides a conservative estimate of the maximum safe drop height. Also, the maximum safe drop height is calculated assuming an ideal impact surface. Under all other conditions, the MSP would require a higher drop height in order to arm.

Using these equations of motion, a computer program was written (Appendix C). An evaluation of the parameters used in the program is shown in Appendix D. The quantity computed by the program is the minimum velocity change required to cause the setback pin to function. The computation is iterated for a variety of values of acceleration, generating a curve of minimum velocity change versus acceleration. A typical curve is shown in fig. 5. This process is then further iterated for a variety of friction coefficients, since it is not possible to make an accurate determination for the value of the friction coefficient in this case. Each curve defines the boundary between a function and a non-function zone. For values of velocity change and acceleration above the curve, the pin will function; and for values below the curve, it will not. Upon examination of the curve shown in fig. 5, it can be seen there is a minimum value of velocity change. For the "no friction" curve in fig. 5, the minimum velocity change is approximately equal to 43.9 ft/sec. An increase in the setback level does not reduce the velocity change required to cause the pin to function. This is due to the fact that the setback duration must also satisfy the MSP before it will function. From this minimum velocity change a drop height can be calculated [Drop Height = $(V_2-V_1)^2/2g$]. The drop height for this no friction curve is about 30 ft. This is the minimum height that the MSP can be dropped from in order to cause it to arm. Below this minimum drop height there is no possible impact surface condition that can cause a combination of acceleration and duration great enough to force the unit to function. This is the maximum safe drop height.

This computer program is used to estimate the required time for the MSP to function at various setback loads, thus simulating different weapon systems. Once the design characteristics of the MSP (i.e., spring strength, helix angle, etc.) have been established, the only other factor which affects the time of

MINIMUM VELOCITY CHANGE vs. ACCELERATION



K= .0474 INCH
R= .0575 INCH
AL= 51.14 DEG
MU= 0 FRICTION
G1= 100 G'S
G2= 300 G'S
X1= .0327 INCH
X2= .0654 INCH
X3= .0327 INCH
AI= 300 G'S
AF= 2000 G'S
I= 50 G'S

SETBACK (G'S)	VELOCITY (FT/SEC)	TIME (SEC)
300	51.8948	5.37647E-03
350	45.9048	4.07648E-03
400	44.3107	3.44305E-03
450	43.9363	3.03463E-03
500	44.087	2.74054E-03
550	44.5074	2.51515E-03
600	45.0796	2.3352E-03
650	45.7416	2.18722E-03
700	46.4582	2.06281E-03
750	47.2078	1.95635E-03
800	47.9768	1.86396E-03
850	48.7562	1.78281E-03
900	49.5401	1.71084E-03
950	50.3243	1.64645E-03
1000	51.1062	1.58843E-03
1050	51.8835	1.5358E-03
1100	52.6551	1.4878E-03
1150	53.4201	1.44378E-03
1200	54.1777	1.40325E-03
1250	54.9276	1.36576E-03
1300	55.6697	1.33098E-03
1350	56.4034	1.29857E-03
1400	57.1292	1.26831E-03
1450	57.8469	1.23996E-03
1500	58.5564	1.21333E-03
1550	59.258	1.18826E-03
1600	59.9519	1.1646E-03
1650	60.6379	1.14223E-03
1700	61.3165	1.12105E-03
1750	61.9878	1.10094E-03
1800	62.6516	1.08182E-03
1850	63.3088	1.06362E-03
1900	63.9589	1.04627E-03
1950	64.6021	1.02969E-03
2000	65.2389	1.01384E-03

MAX DROP HEIGHT= 29.9993 FT

FIGURE 5
CURVES

setback durati n required for the pin to function, is the magnitude of the setback force. Hence, in order to determine the time required for the MSP to function in a particular gun, it is only necessary to know the setback associated with that gun for a particular charge. A list of setback versus duration is shown in Appendix E. The design characteristics used in this program are taken from units used in the final ballistic test conducted in May 1983.

In actual use, the setback duration required to function will vary from 1.3 milliseconds with a 4.2" mortar in Zone 0 to .3 milliseconds in a 105mm Howitzer Zone 7.

A modified version of this program is also used to provide a comparison of the relative importance of nine design features as they relate to the maximum safe drop height (see Appendix F). This information can be very useful in determining more exactly what tolerances are acceptable. This may be important because the current need to chemically etch each part lends itself to large dimensional variations between lots.

AUTOMATED ASSEMBLY

Since the MSP is a self-contained entity capable of being assembled and tested outside the fuze, it is a natural candidate for automation. The following is a conceptual study of automated assembly and testing equipment. The automated assembly portion of this study was conducted in cooperation with Mikron Haesler Limited.

For the purpose of assembling the MSP, Mikron Haesler has proposed using a modified Polyfactor machine, type 90-1-18. The machine is a fully automatic rotary transfer assembly machine comprised of 18 stations, and all feeding, transfer and inspection devices, including laboratory feed bowls and a memory/control system. In addition to normal main machine control, this memory/control system will be used in conjunction with inspection devices located around the machine. The inspection devices are utilized to verify the "condition" of the piece parts as they are introduced to the machine fixtures. Conditions such as presence and position would be "sensed." The information obtained by the individual inspection devices is relayed and accumulated by the memory/control system which, subsequently, instructs the succeeding work, and transfer units, to suspend or continue operations relative to the component piece part condition. The memory section also instructs the ejection stations to separate "good" units from "faulty" or incomplete units. This ability could be utilized to detect broken housing spring supports at Station 12 (see Operation Sequence). This is the biggest part defect we have seen thus far.

All of the component piece parts contained in the assembly, with the exception of the spring, are proposed to be vibratory bowl fed. The spring will be produced by an automatic spring winder at the assembly machine. These springs will be 100% tested immediately after assembly and the reject rate can be recorded by the memory/control. If the reject rate becomes too high, the memory/controller can be programmed to stop operations and wait for adjustments.

The following is the operation sequence for the assembly of the MSP submitted to HTI by Mikron Haesler. The machine is designed to run at a four-second cycle rate, but this time can be reduced if need be. The price for this Polyfactor assembly machine, including a "Modicon" brand memory/control system and a factory trial run, was quoted at approximately $247,000.*

Sequence of Operation:

Station	Operation	Equipment
1	Feed and transfer "setback pin" nest (1)	Bowl Feeder
2	Inspect presence and position "setback pin"	
3	Invert "setback pin" if required	
4	Orient "setback pin"	
5	Transfer "setback pin" to nest (2)	

* 1983 dollars

Station	Operation	Equipment
6	Inspect presence and position "setback pin"	
7	Vacant	
8	Feed and transfer "spring" nest (2)	Spring Winder
9	Inspect presence and position "spring"	
10	Feed and transfer "housing " nest (3)	Bowl Feeder
11	Orient "housing"	
12	Inspect presence and position "housing"	
13	Transfer "housing" and rotate to lock-in position	
14	Inspect presence, position and movement of "housing"	
15	Vacant	
16	Eject and separate good/bad assemblies	
17	Eject partial assemblies	
18	Inspect empty nests	

After the assembly operations have been completed, the units would automatically be loaded onto a testing machine. HTI has envisioned the testing machine to be compromised of six (6) 10" spin tables all mounted on a 44" diameter rotary table (see fig. 6). The cycle rate for the testing fixture would be geared to the rate of the assembly machine. By doing this, the machine could take advantage of the setback pin positioning already done by the assembly machine. Each of the six spin tables would hold ten setback pins and would be controlled by identical stepper motors mounted underneath the large table. A controller at each of the six divisions of the large index table determines the action of the individual internal spin tables; that is, as the large table indexes, the controller's electrical contacts for each of the six fixed positions is engaged for the individual motor at that position. The motor, which first "homes" into a constant nest position, then makes ten consecutive steps for one revolution, or spins at a preset speed depending on the controller setup.

Setback units are transferred from the assembly machine to the testing machine at station no. 1. The large table then indexes to station no. 2. Setback units that arm at station no. 2 (non-arm spin) are photo-optically detected for lack of pin projection and ejected at station 3. Any units that fail to arm at station 4 are photo-optically detected for pin projection and automatically ejected at station 5. All parts off of station number 6 are good and the spin table is emptied in preparation for reloading at station number 1.

SPECIAL AUTOMATIC TESTING MACHINE
MODULAR SETBACK PIN

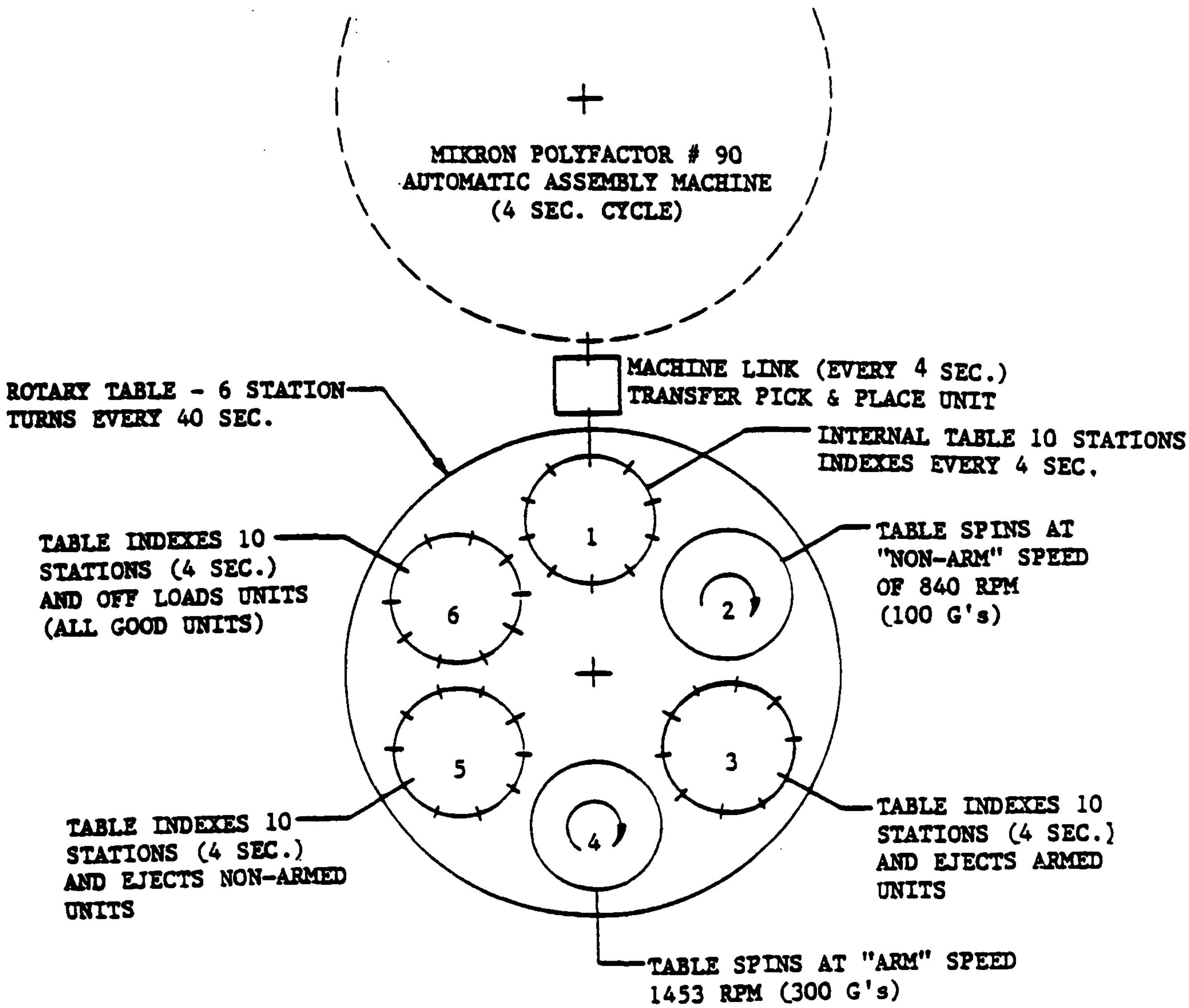


FIGURE 6
AUTOMATIC TESTING MACHINE

Inspections for presence would be performed after each loading and unloading operation. The location of these devices and the transfer units themselves would be on a stationary surface just outside the large index table. It is HTI's estimate that this test machine can be designed, built and installed for approximately $160,000.*

* 1983 dollars

MANUFACTURABILITY

To manufacture the die castings for the modular setback pin, state-of-the-art die-making techniques were involved. A special tool was built to generate the helical-radial sides of the Z-groove and cam. This was used to make a 10:1 scale model of the complex surfaces. From those models, the dies were made by a reducing pantograph.

When the first parts were made from these dies it was found that a serious problem existed in measuring the complex surfaces. A number of methods were considered and all were eliminated as being unfeasible, except for the toolmaker's microscope. Even this proved inadequate, since its repeatability in this application was greater than the tolerance on the dimensions being measured.

Ultimately, the criterion for acceptance of the parts was their ability to interact properly. As cast, the parts would not fit together, the cam being too large for the track - or the track being too small for the cam. The critical dimensions were then adjusted by chemical etching, first by a proprietary process by the manufacturer, then by a final etching of the housing at HTI. This etch schedule is given in Appendix G. Because the etching done by the manufacturer was not tightly controlled by the manufacturer, it was necessary to vary the in-house etch time on a lot-to-lot basis.

The parts used in the final testing had some secondary operations used in their manufacture for reasons of efficiency. Specifically, these were cutting the slot in the housing and cutting the flats on the housing's mounting flange. In production, these features will be cast. It was simply faster to machine them than to change the dies at that point. The same argument applies to the changes to the timer spin detent, which is also a zinc die casting.

ENGINEERING TEST PROGRAM

A complete modular setback pin ballistic test summary is shown in Appendix H. The first fuzes with modular setback pins were tested in May, 1980, with the results shown in Table 1.

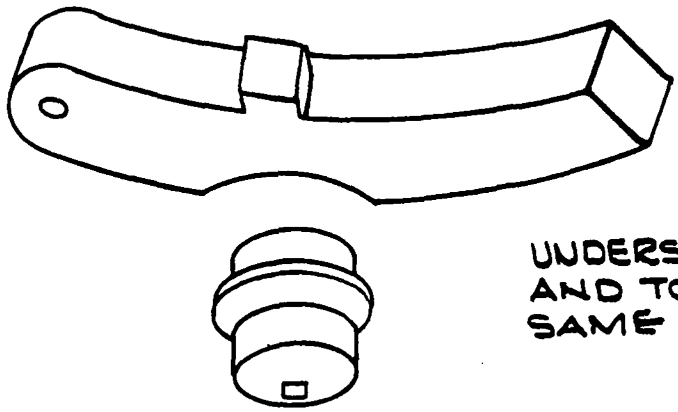
Gun	Zone	Fuze setting	Rounds fired	Rounds functioned
105-mm	7	50 s	5	5
8-in	1	15 s	5	2
155-mm	1	PD	5	5

TABLE 1

The success in the low zone PD test, compared to the high dud rate in the low zone airburst test, suggested that the problem was in the timer setback pin, and not the setback pin in the trigger. The duds were recovered, and it was found that the timers had either stopped or had never run. The reason for this was not apparent. In the same time period, five fuzes were air gun tested at approximately 30,000 g. Of the ten modules involved, five had the cams sheared off the inside of their housings.

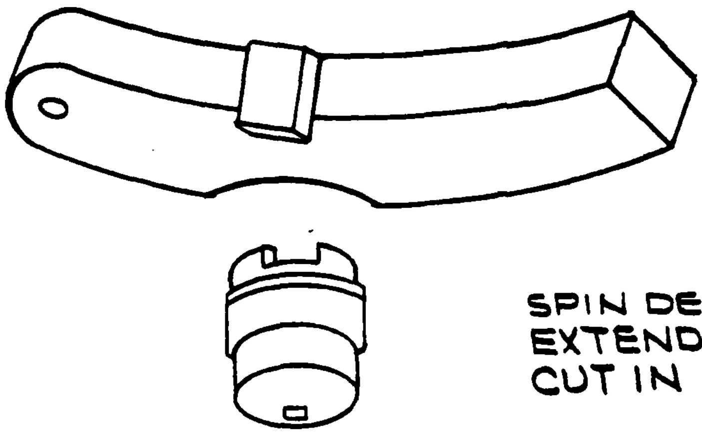
Based on the results, two new tests were planned. Twenty-four fuzes were built for an 8-in., zone 1, vertical recovery test, and twelve fuzes were built for a 105-mm 8, recovery vehicle test. These were fired in August 1980. In all of the high zone tests, the modules functioned properly. The modules were functional afterwards, indicating the cam had sufficient strength for normal gun firing. In the low zone recovery test, four fuzes failed to function. On examination, it was found that the timers had not run. While the reason for this was not apparent, it was found that a modification made to the spin detent, to allow it to pass over the setback pin module, also allowed the balance wheel to be released under some conditions. Modifications to the spin detent and housing, as shown in figure 7, solved this problem. The lug on the spin detent, which engages the blance wheel was extended downward, and the housing was notched to allow the extended lug to pass outward.

Sixteen fuzes of the first modification design were built and fired in recovery vehicles at low zone. On November 1980, twelve fuzes were recovered, and two of these had failed to function. It was found that in the fuzes, which had functioned properly, the pins were retracted and locked down. In the failed units, the pins were fully up. While no reason for this was apparent, it was found that the modules were free to rotate, which could have allowed the housing slot to move out of line with the path of the spin detent lug. To solve this problem, the shape of the housing's mounting flange was altered to have flats, as shown in figure 8. The opening in plate 4 was modified to have a matching shape. It was speculated that another possible cause of the failures was a marginal strength spring, although the springs tested satisfactorily.



UNDERSIDE OF SPIN DETENT AND TOP OF HOUSING ON SAME PLANE

ORIGINAL DESIGN
FOR MODULAR CONCEPT



SPIN DETENT LUG EXTENDED AND NOTCH CUT IN HOUSING

FIRST MODIFICATION

FIGURE 7
INTERACTION OF TIMER SPIN DETENT AND HOUSING

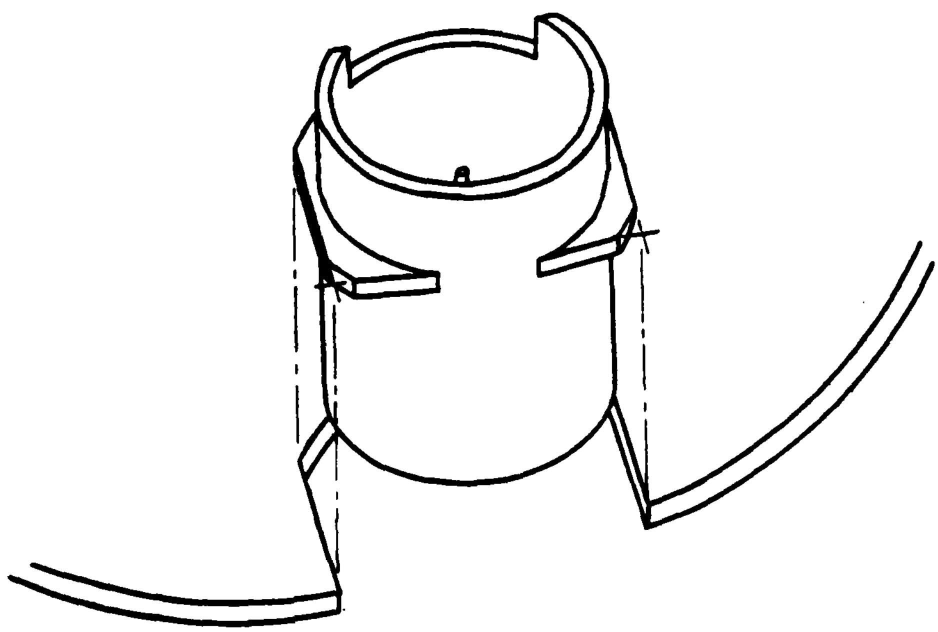


FIGURE 8

SECOND MODIFICATION

FLATS ON HOUSING AND PLATE 4 TO PREVENT ROTATION statically, they could possibly be too strong in a dynamic environment. In further analysis, a comparison was made between the two enclosures in which the modules are placed in the fuze, since all failures had been encountered in timers, and none in triggers.

It was determined, the greatest difference between the two locations was that the timer no. 1 plate forms a wall outward of the pin, as shown in figure 8, and there is no similar feature in the trigger where the pin stands free.

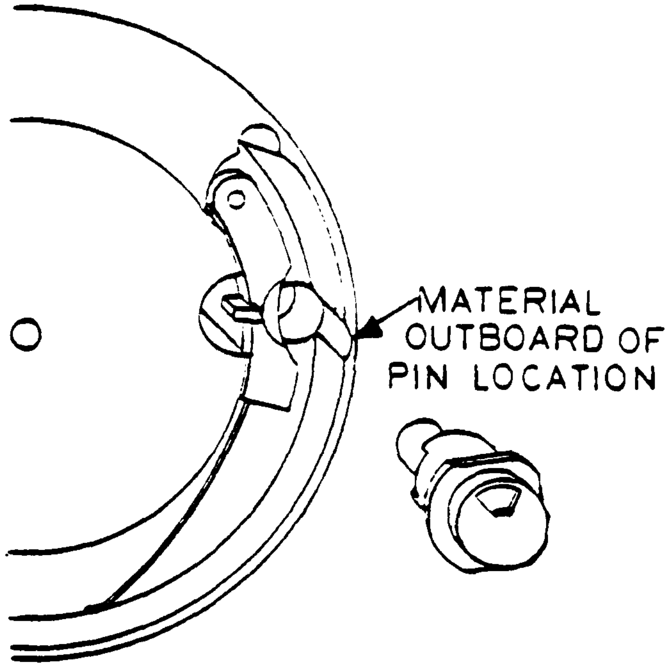
Two groups of twenty test fuzes each were built. Both groups had the flats on the mounting flange. One group had weaker springs, and the other group had material removed from the sidewall of plate no. 1, as shown in figure 9. Eighteen fuzes from each group were fired in recovery vehicles at low zone in March, 1981. The group with the weaker spirngs had a high failure rate. Those with the relief cut in plate no. 1 had two failures of the timer to operate. However, in each of these latter failures, the pins were down and locked, yet the spin detents were still blocked.

On close examination, it was found that the top of each locked-down pin was slightly above the housing, rather than flush with it. The reason for this is the interaction of the Z-groove and diamond cam, as shown in figure 10. While the locked position was designed to be as shown in the upper view, which puts the top of the pin flush with the top of the housing, the configuration shown in the lower view also provides effective locking, but in this case the pin is approximately .015" above the top of the housing. It was not feasible to lower the module, nor to reduce its size further. Therefore, it was decided to remove some material from the spin detent, allowing it to pass over the pin in either of the locked-down configurations. This is shown in fig. 11.

Thirty fuzes were built using the configuration described above, and including all previous modifications. These were fired in June of 1981, in low zone recovery vehicles. All fuzes were recovered and all were found to have functioned properly.

Based on these previous results, a larger test program with 200 units was prepared. The test started; however, due to a large number of duds, it had to be stopped prematurely. Thirty recovery rounds were fired to analyze the problem. Fifteen were fired in the 155-mm zone 8, cold, and set for 75 seconds. Four of the fuzes failed to function but, when the setback pins were examined, all were found to have locked down in the timer and all but one were locked down in the trigger. The other fifteen rounds were fired in the 155-mm zone 1, cold, and set for thirty seconds. Only eight of the fifteen rounds functioned; however, there were just two setback pins in the timer that were not locked down, and one in the trigger. So, although the setback pins could not be blamed for the entire problem, there were nevertheless some difficulties with the setback pins. All of the work accomplished up to this point was done on a previous MSP contract, number DAAK10-77-C-0152 (CPFF).

On this latest MSP contract (DAAK10-82-C-0132), a test program involving 121 units was planned. The following changes were performed to these MSP units:



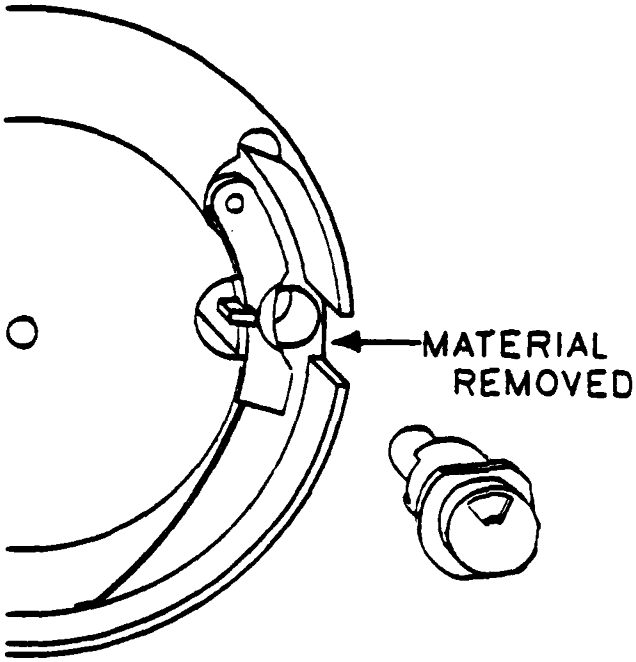
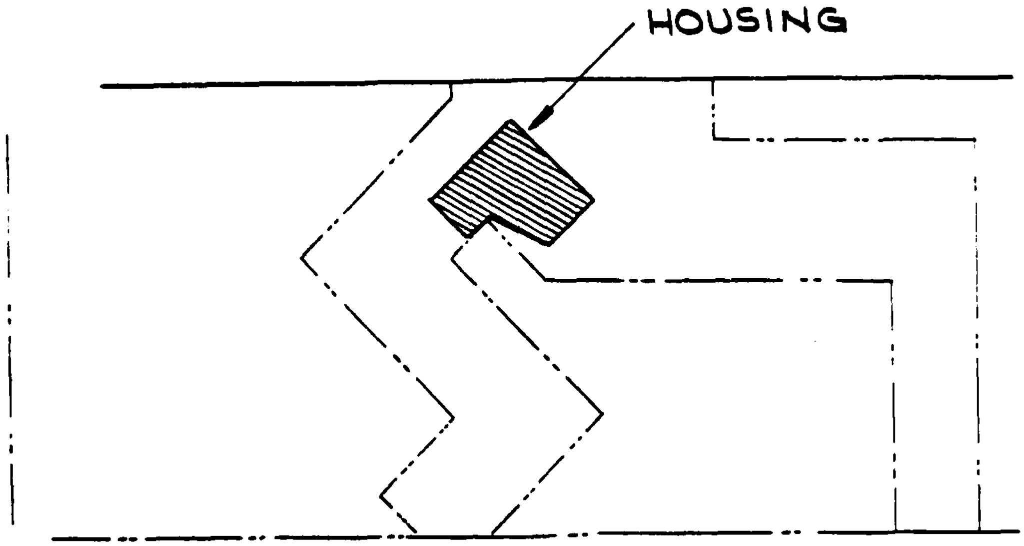
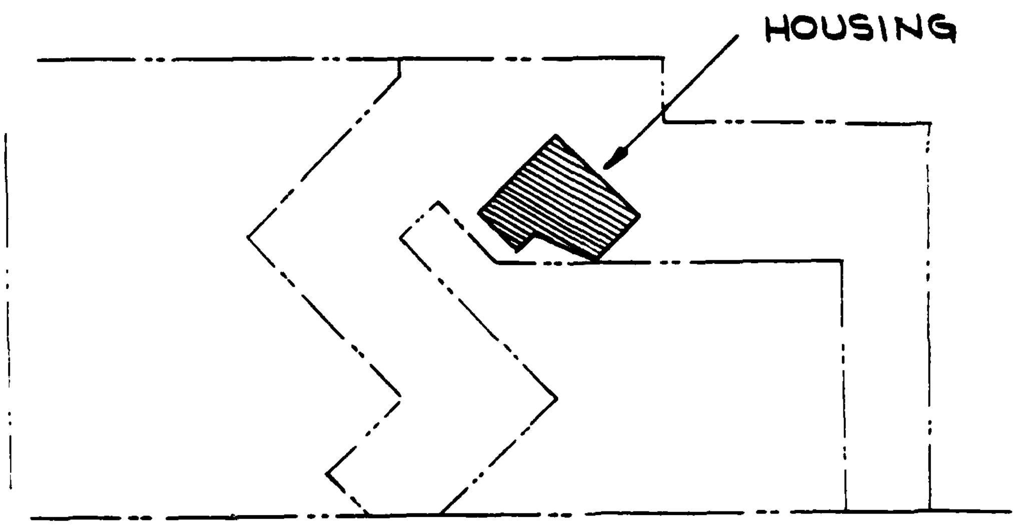


FIGURE 9
THIRD MODIFICATION
MATERIAL REMOVED FROM SIDEWALL
OF PLATE NO. 1



INTENDED LOCK POSITION



ALTERNATE LOCK POSITION

FIGURE 10

RELATIVE LOCATIONS OF Z-TRACK & CAM

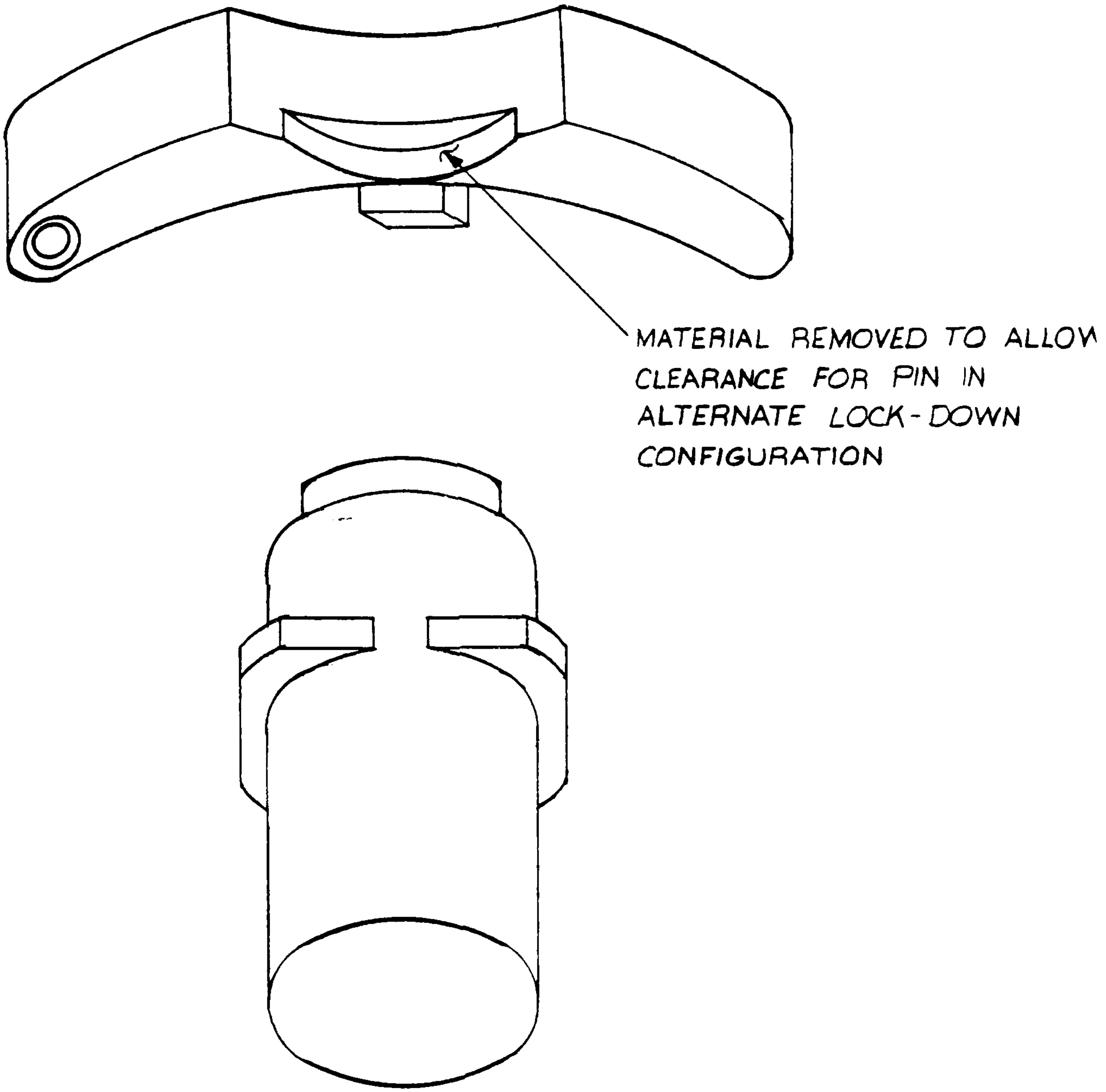


FIGURE 11
FOURTH MODIFICATION

Lighter Springs

All units tested incorporated a lighter spring that required an average of 256g's to compress them. Previously, springs required about 600g's. Although the springs were lighter, these units were still able to pass a 40-foot drop test.

100% Cycling

After a light etching, all units were cycled at least 70 times. The major problem we have been experiencing with these MSP units is that the cam in the housing is oversized. Cycling reduces this cam size without reducing the size of the rest of the unit as etching does.

100% Centrifuge Testing with a 400g Function Cut-off Point

All units that required more than 400g's to function were rejected. There was no definitive cut-off point in previous tests.

NO Vydax

The units tested had no lubrication at all. Since Vydax wears away with prolonged friction, it would serve no purpose to have it in these units which were to be cycled 70 times. Also, the Vydax could possibly get gummy in the cold test and do more harm than good.

With the aforementioned changes made, a 121 fuze ballistic test was performed. This latest test was a 100% success. All 242 setback pins in 121 fuzes functioned properly. Even the 8" zone ½, which had two duds in the control group, functioned perfectly. The control group may have experienced a "cross-over" problem. This is a situation in which the setback force subsides before the spin detents have a chance to move out. The setback pin would then come back up locking out the spin detent. This cannot happen with the MSP since it is designed to lock down after setback.

There were three duds in the rough handling group; however, such fuzes are only required to be safe to handle and fire. The X-rays of these rough handling duds did show the modular setback pins in the safe position after rough handling.

The most significant change made to this last test was the 100% cycling. Cycling the units assured that they were capable of moving freely. This would not be necessary if the parts were made to drawing tolerances. The complete success of this latest ballistic test proves the present MSP configuration can be both relaible and safe.

CONCLUSIONS AND RECOMMENDATIONS

The modular setback pin described in this report has shown the potential to improve the reliabilty of the M577 fuze. The MSP provides excellent performance in all drop test environments and functions reliably in all gun-firing environments. Its ability to lock down after setback can eliminate the "crossover problem." The MSP has the potential to be less expensive to manufacture than the present setback pin systems. The MSP also offers ease of assembly due to its self-contained design; the fact that the same unit can be used in both the trigger and timer and because of its ability to lock down during testing. Also, the MSP can be tested outside the fuze prior to assembly.

Although the MSP design has proven feasible, an additional engineering effort will be required before it is ready for production. This is due to the extreme complexity of the die-cast housing and pin. The parts presently used do not fit together as cast; they had to be etched in order to reduce the size of the housing cam. Of course, this also reduced the dimensions which were not oversized causing additional problems. Cycling, as was done in the last ballistic test, could eliminate this problem but would be extremely costly for production size quantities. Therefore, to correct this problem, the manufacture of a new Housing die insert will be necessary. However, care must be taken to avoid the problems encountered with the first die.

The root of these difficulties is our inability to accurately measure these complex surfaces. We were therefore forced into the undesirable position of accepting parts based on their ability to interact properly. Etching had to be performed on a trial and error basis. This problem of accurate measuring must be addressed before production can be considered practical.

Therefore, it is recommended that additional engineering work be performed to reduce these problems before implementation. Using the computer study supplied in this report, it may be possible to increase some non-critical tolerances and increase the Z-groove width to ease manufacturing and reduce the need for etching. One possible method for the accurate measurement of these die cast parts is to section sample parts in such a manner that critical dimensions could be measured along flat surfaces. This method would not be useful in measuring one particular part, but rather a large group of parts. Die casting generally produces parts with a high degree of consistency so once the dimensions of one part is known it can be assumed that all the parts will be very similar. Reproducibility is exceptionally exact with the state-of-the-art processes used by Gries Dynacast to make the MSP. Other difficulties such as the cam shearing in the 30,000g air gun test and the breaking of the housing spring supports could also be avoided. This may be accomplished by going to a stronger material such as Zamak No. 5. The problems caused by allowing two lock down positions could be eliminated with a minor die change that would force the cam into its original lock down configuration (see figure 12). Also, the need for a cutout on the no. 1 plate should be further investigated.

The MSP design has proven to be beneficial in terms of reliability; but, due to the manufacturing difficulties, it is not being recommended for implementation at this time.

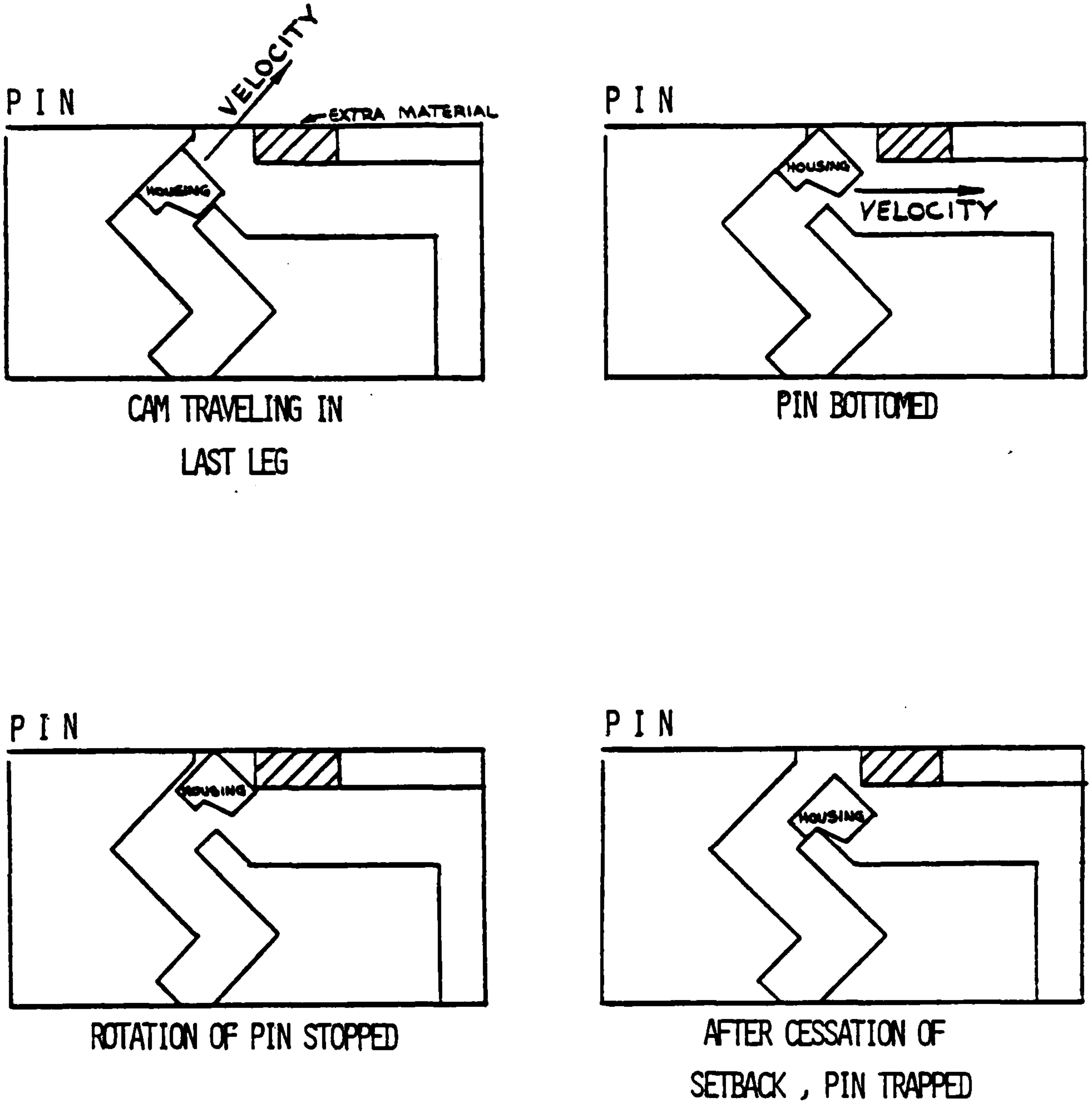
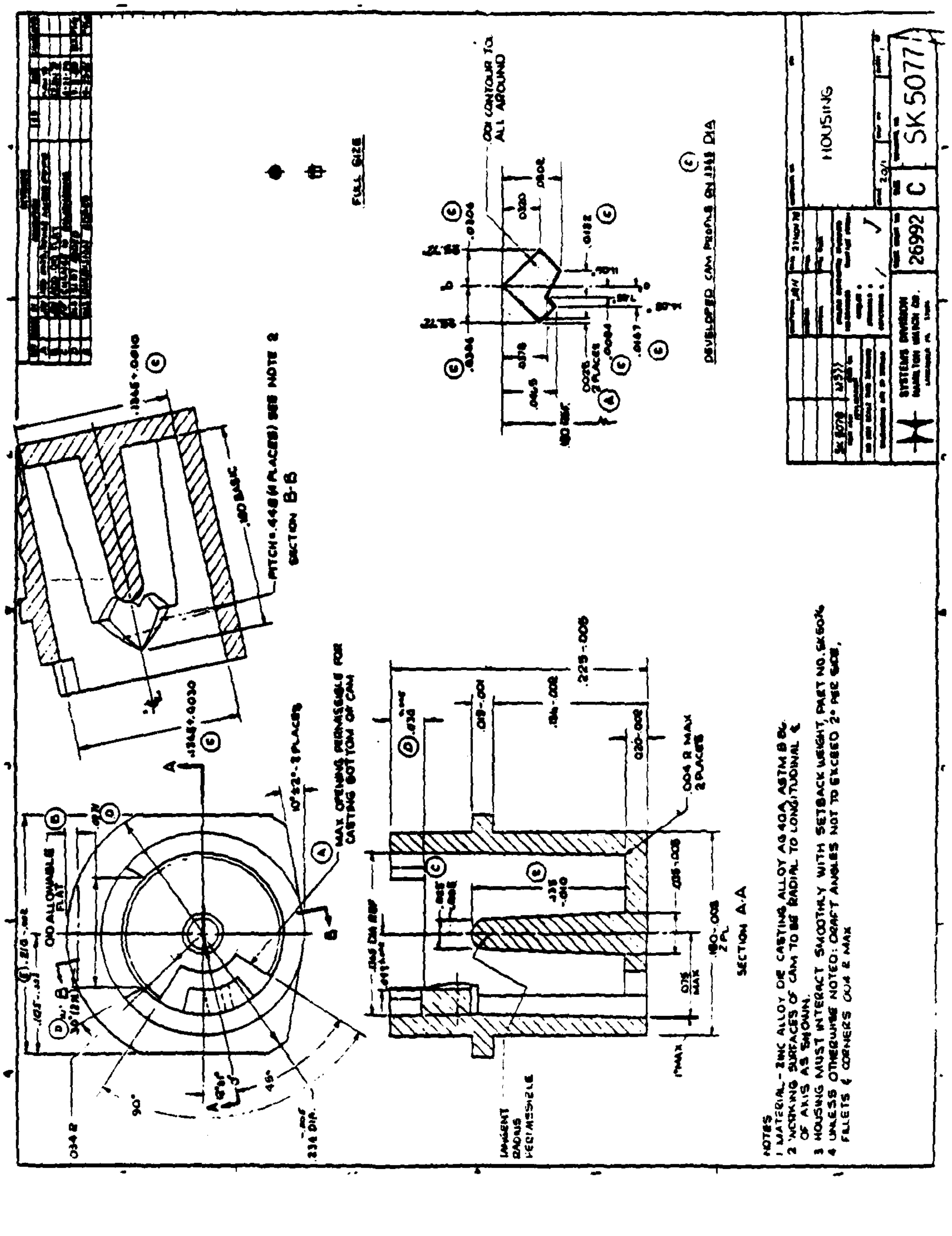


FIGURE #12

LOCK-DOWN FEATURE WITH DIE CHANGE

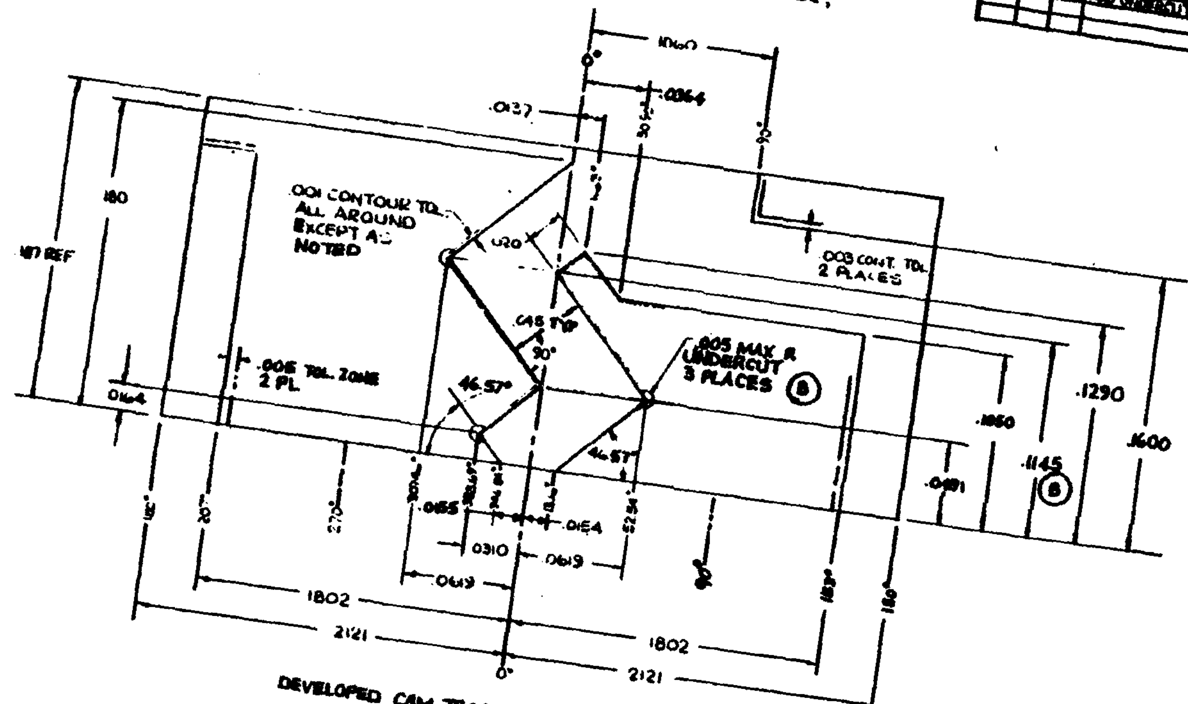
APPENDIX A

REQUIRED DRAWING CHANGES


HOUSING
SK5077
26992
SECTION A-A
SECTION B-B
FULL SIZE
DEVELOPED CAM PROFILE
NOTES

NOTES—
1. MATERIAL - ZINC ALLOY DIE CASTING, ALLOY AG40A, ASTM B 86
2. WORKING SURFACES OF CAM TO BE RADIAL TO LONGITUDINAL ℄ OF AXIS AS SHOWN.
3. SETBACK WEIGHT MUST INTERACT SMOOTHLY WITH HOUSING, PART NO. SK5077
4. UNLESS OTHERWISE NOTED: DRAFT ANGLES NOT TO EXCEED 2° PER SIDE, FILLETS AND CORNERS .004 R MAX.

LTR		BY	REVISIONS			
A			ADD .005 FLAT			
B			ADD UNDERCUT & .1145			



DEVELOPED CAM TRACK PROFILE ON .135 DIA

FULL SIZE

SK5078	M877
NEXT ASSY	USED ON
APPLICATION	
DO NOT SCALE THIS DRAWING	
DIMENSIONS ARE IN INCHES	

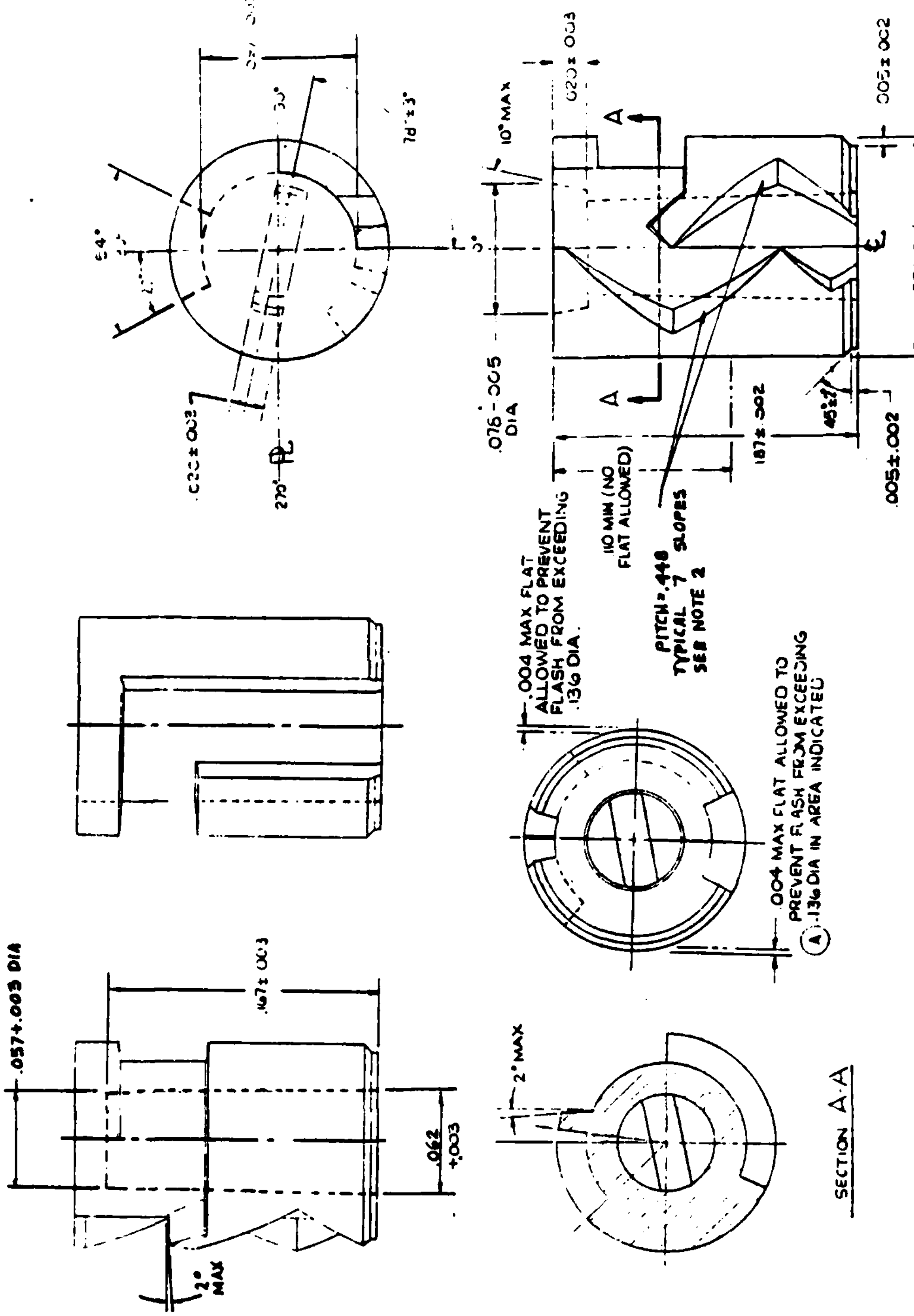
DRAFTSMAN JEH DATE 31 NOV 70

UNLESS OTHERWISE SPECIFIED TOLERANCES ANGLES ± DECIMALS ± FRACTIONS ± SURFACE FINISH √

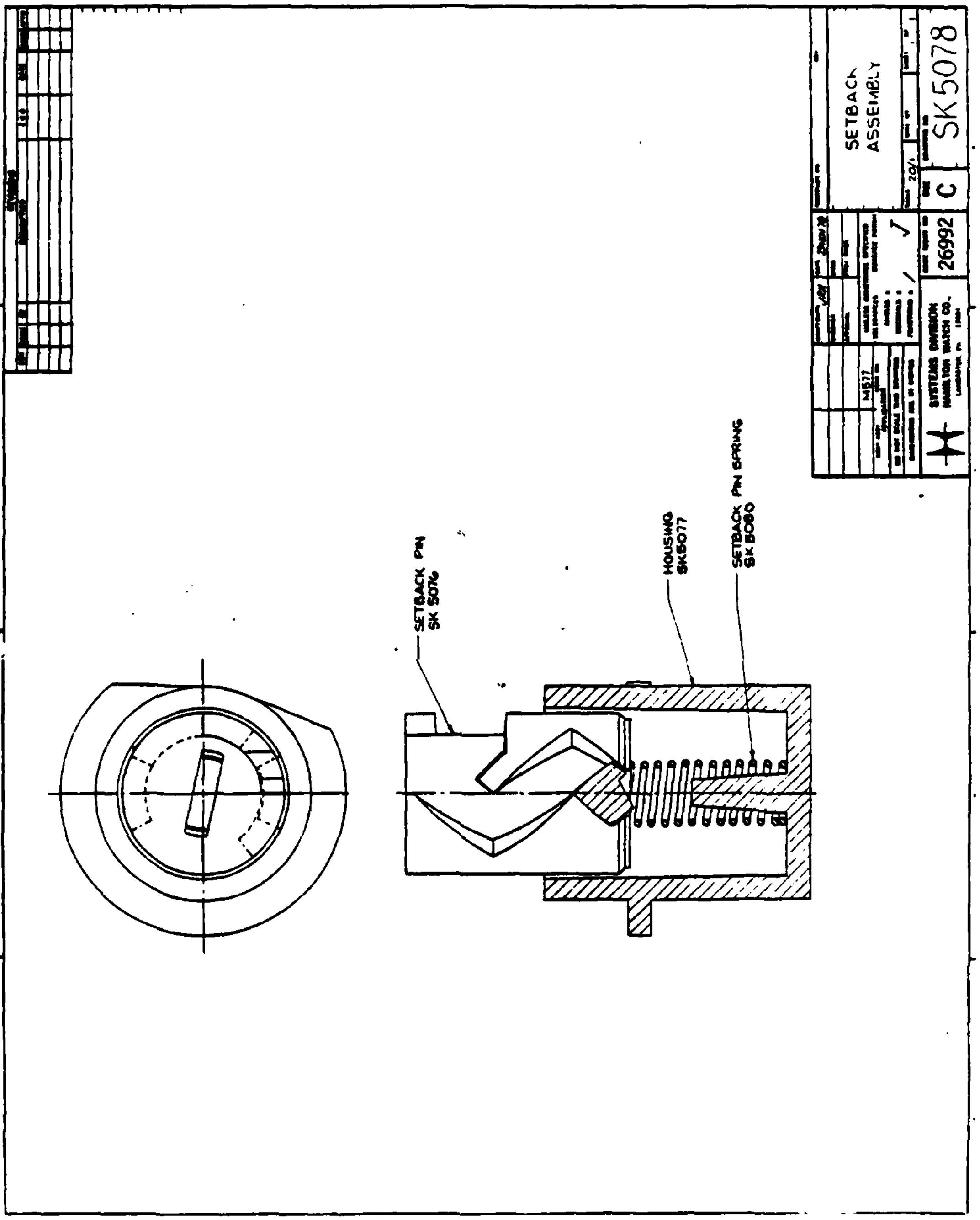
SYSTEMS DIVISION
HAMILTON WATCH CO.
LANCASTER, PA. 17604

SETBACK PIN

CODE IDENT NO. 26992 SIZE D DRAWING NO. SK5076 SCALE 20/1



.057+.003 DIA
.167±.003
.062 +.003
2° MAX
2° MAX
SECTION A-A
.004 MAX FLAT ALLOWED TO PREVENT FLASH FROM EXCEEDING Ⓐ .136 DIA IN AREA INDICATED
.004 MAX FLAT ALLOWED TO PREVENT FLASH FROM EXCEEDING .136 DIA
PITCH=.448 TYPICAL 7 SLOPES SEE NOTE 2
110 MIN (NO FLAT ALLOWED)
.187±.002
.005±.002
45°±1°
.135±.001
.005±.002
.020±.003
10° MAX
.076-.005 DIA
270°
.020±.003
3° ±3° PL


SETBACK PIN
SK 5076
HOUSING
SK5077
SETBACK PIN SPRING
SK 5080
SETBACK
ASSEMBLY
C
SK5078
26992
SYSTEMS DIVISION
HAMILTON WATCH CO.

REVISIONS							
REV	ZONE	BY	DESCRIPTION	ECO	DATE	CHKD	APPD

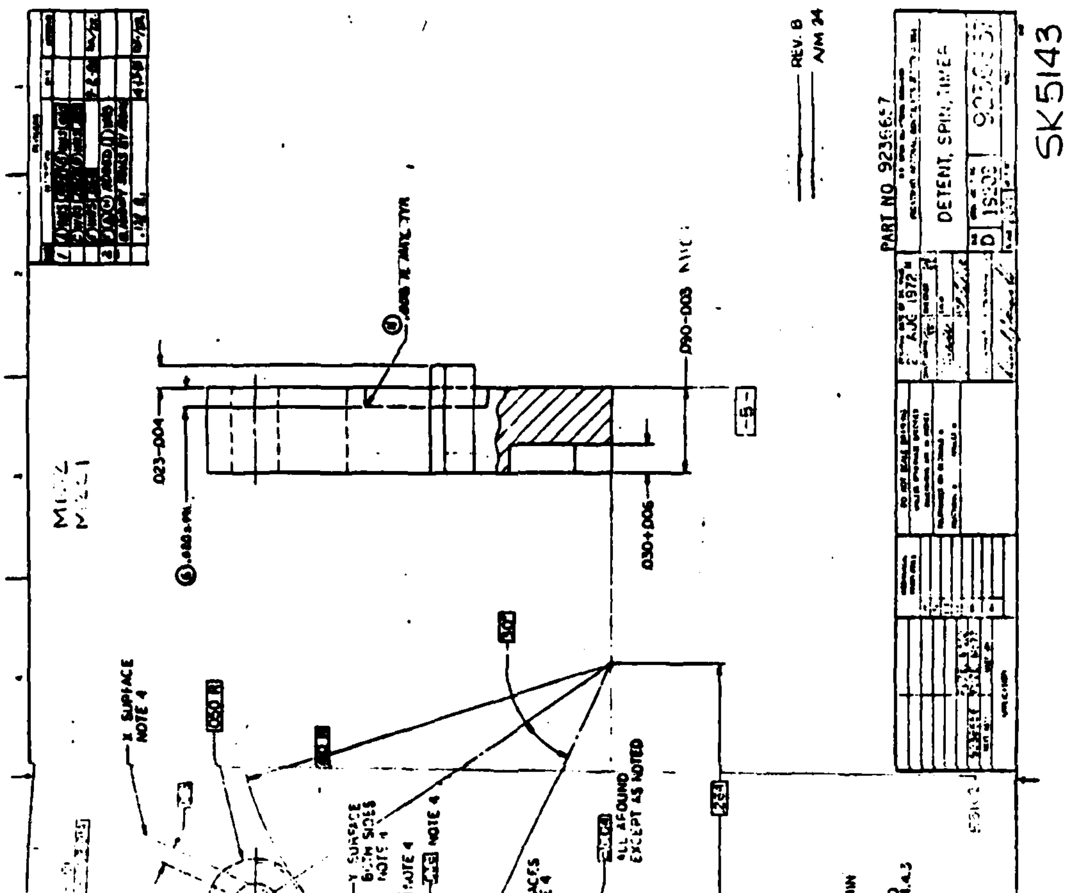
SPRING DATA

1. MATERIAL - CRES 302
2. DIRECTION OF WIND - LEFT HAND
3. SPRING MUST OPERATE FREELY IN .057 DIA BORE AND OVER .035 DIA PIN
4. LOADS - .119 LB. MIN. (54 GM.) @ .296 LENGTH
   .228 LB. MAX (103 GM.) @ .164 LENGTH

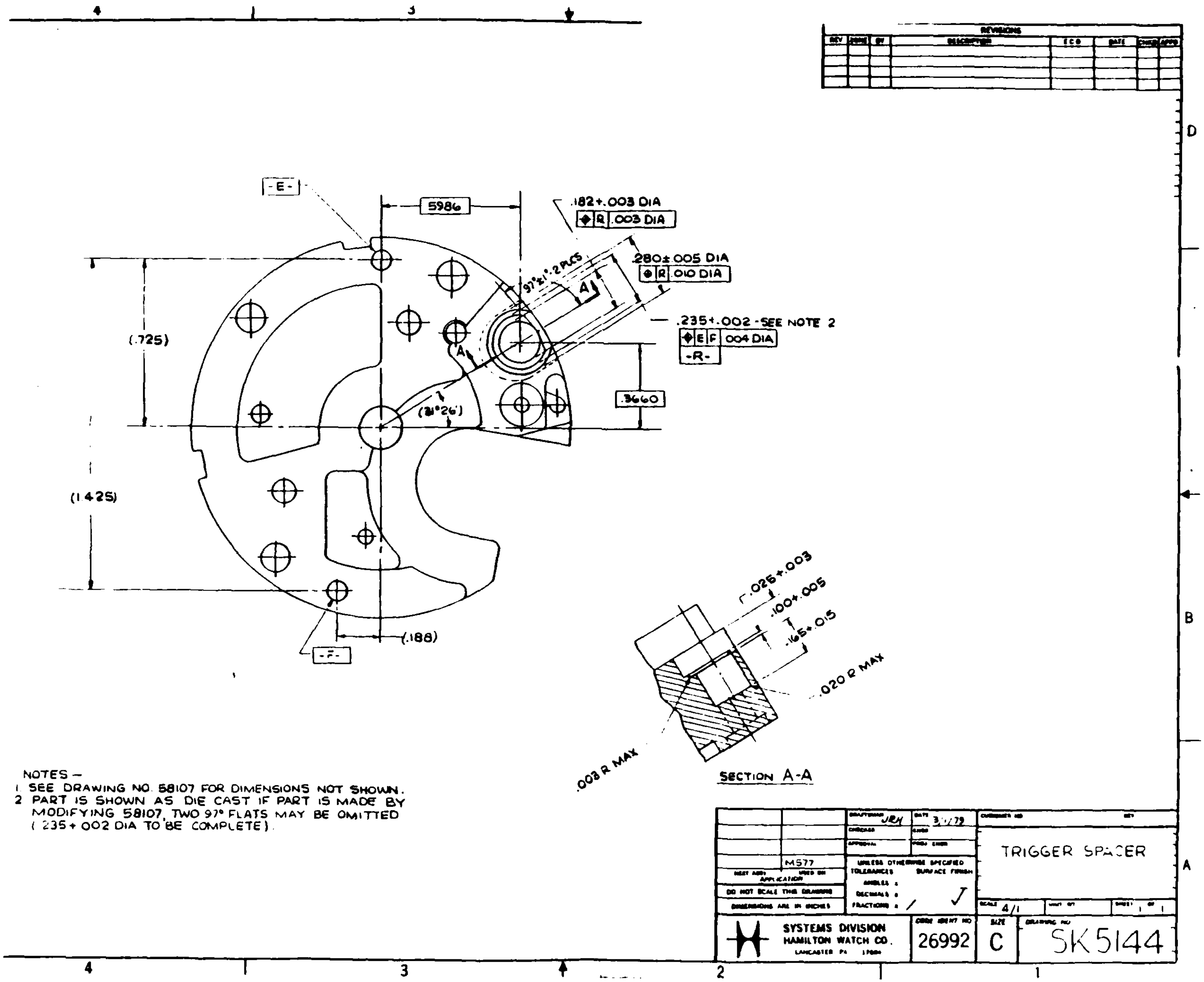
ADVISORY INFORMATION

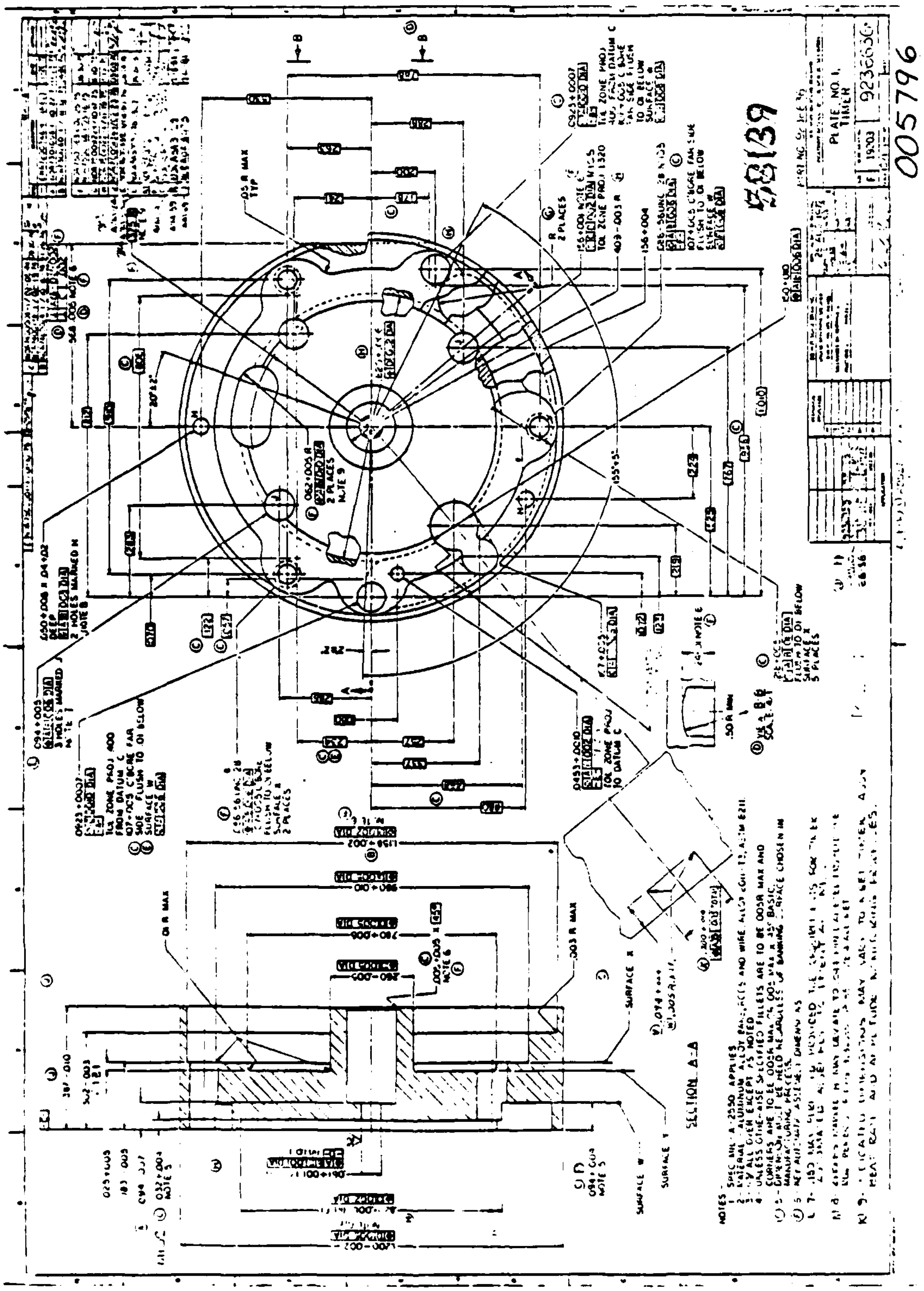
1. WIRE SIZE - .006 DIA
2. TOTAL NO. OF TURNS - 25
3. STYLE OF ENDS - 1 CLOSED ON EACH END
4. OUTSIDE DIA - .050
5. FREE LENGTH - .426

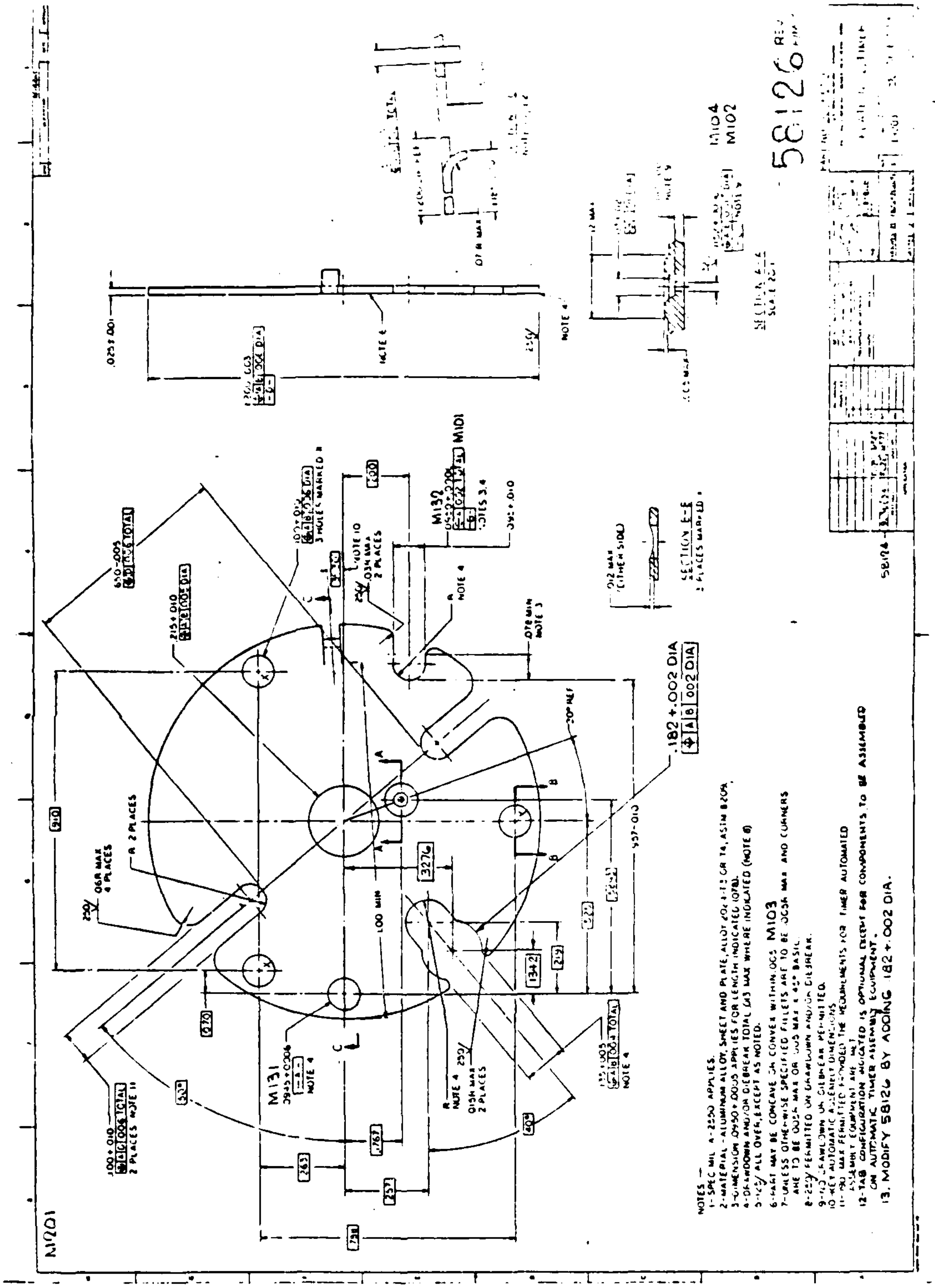
NEXT ASSY. / USED ON — APPLICATION	
DO NOT SCALE THIS DRAWING	
DIMENSIONS ARE IN INCHES	
DRAFTSMAN JRH	DATE 1-3-79
CHECKER	ENGR.
APPROVAL	PROJ. ENGR.
UNLESS OTHERWISE SPECIFIED TOLERANCES: ANGLES ± / DECIMALS ± / FRACTIONS ±	SURFACE FINISH √
CUSTOMER NO	REV.
SPRING	
SCALE —	UNIT WT
SHEET 1 OF 1	
SYSTEMS DIVISION HAMILTON WATCH CO., LANCASTER, PA. 17604	CODE IDENT NO. 26992
SIZE B	DRAWING NO. SK5080

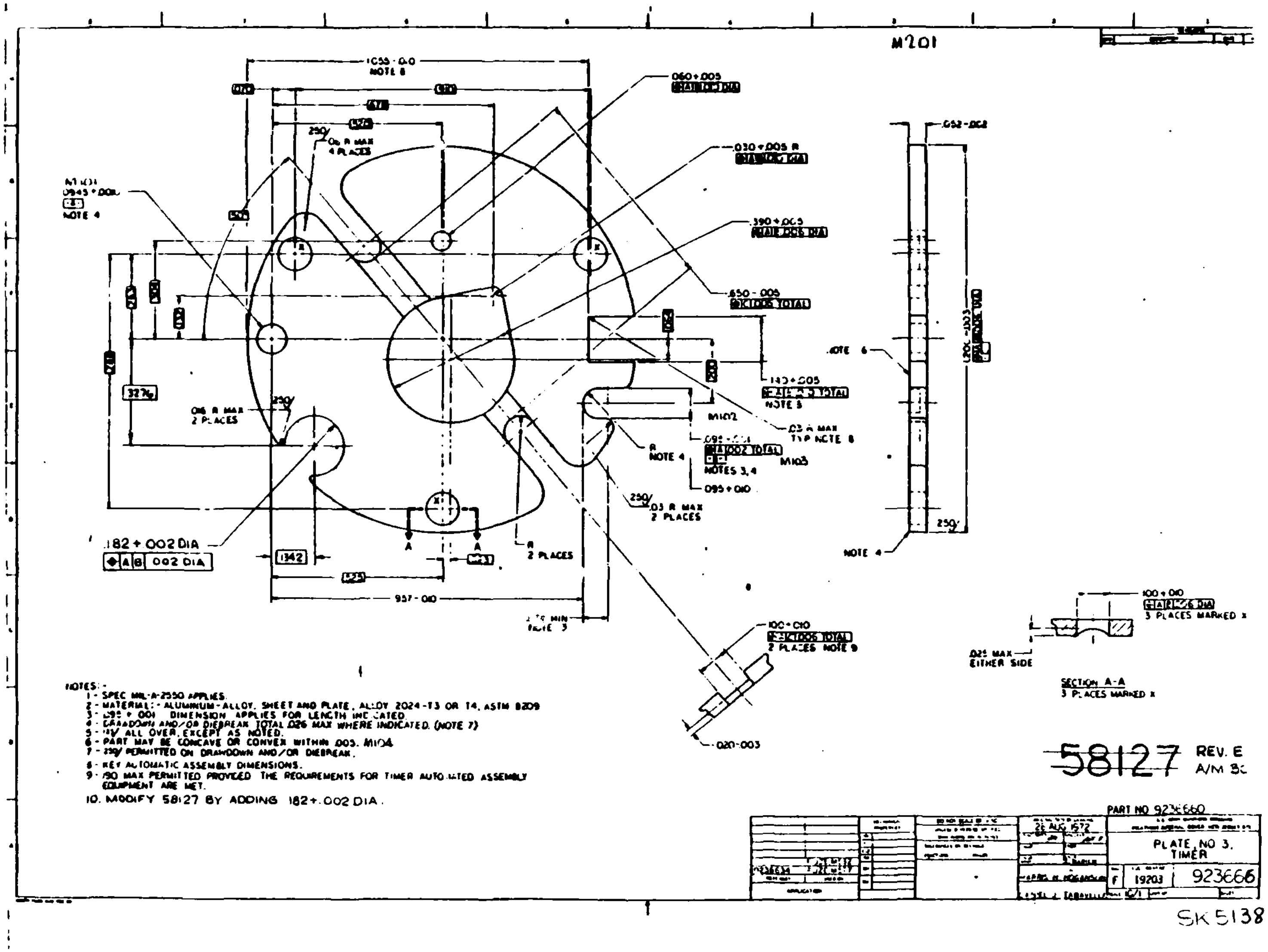


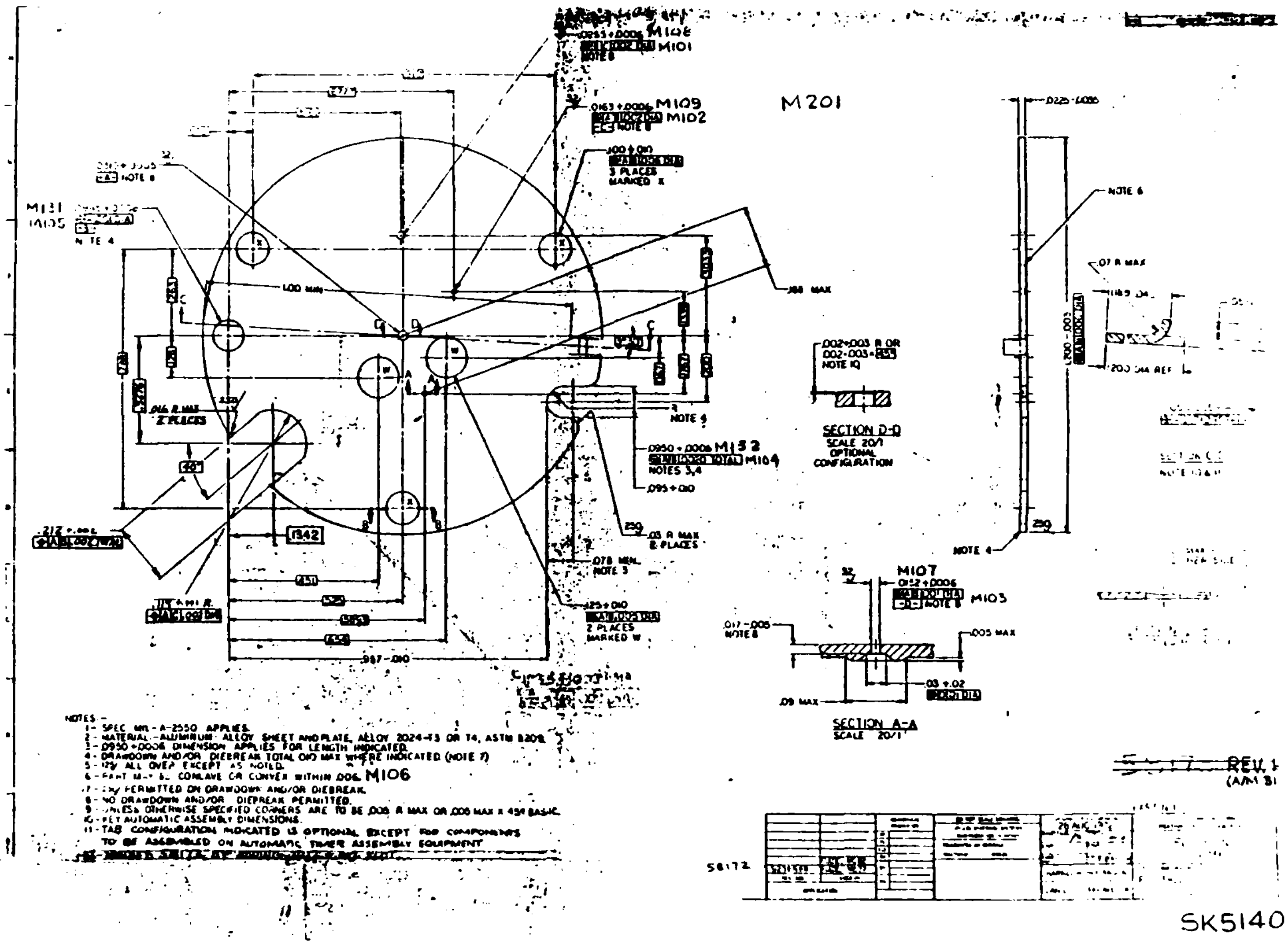
SK5143
REV. B
X SURFACE NOTE 4
Y SURFACE BOTH SIDES NOTE 4
ALL AROUND EXCEPT AS NOTED
2 PLACES NOTE 4
.01 R MAX 2 PLACES
70° MIN NOTE 5
AROUND ENTIRE SLOT
.02 R MAX
DETENT, SPIN

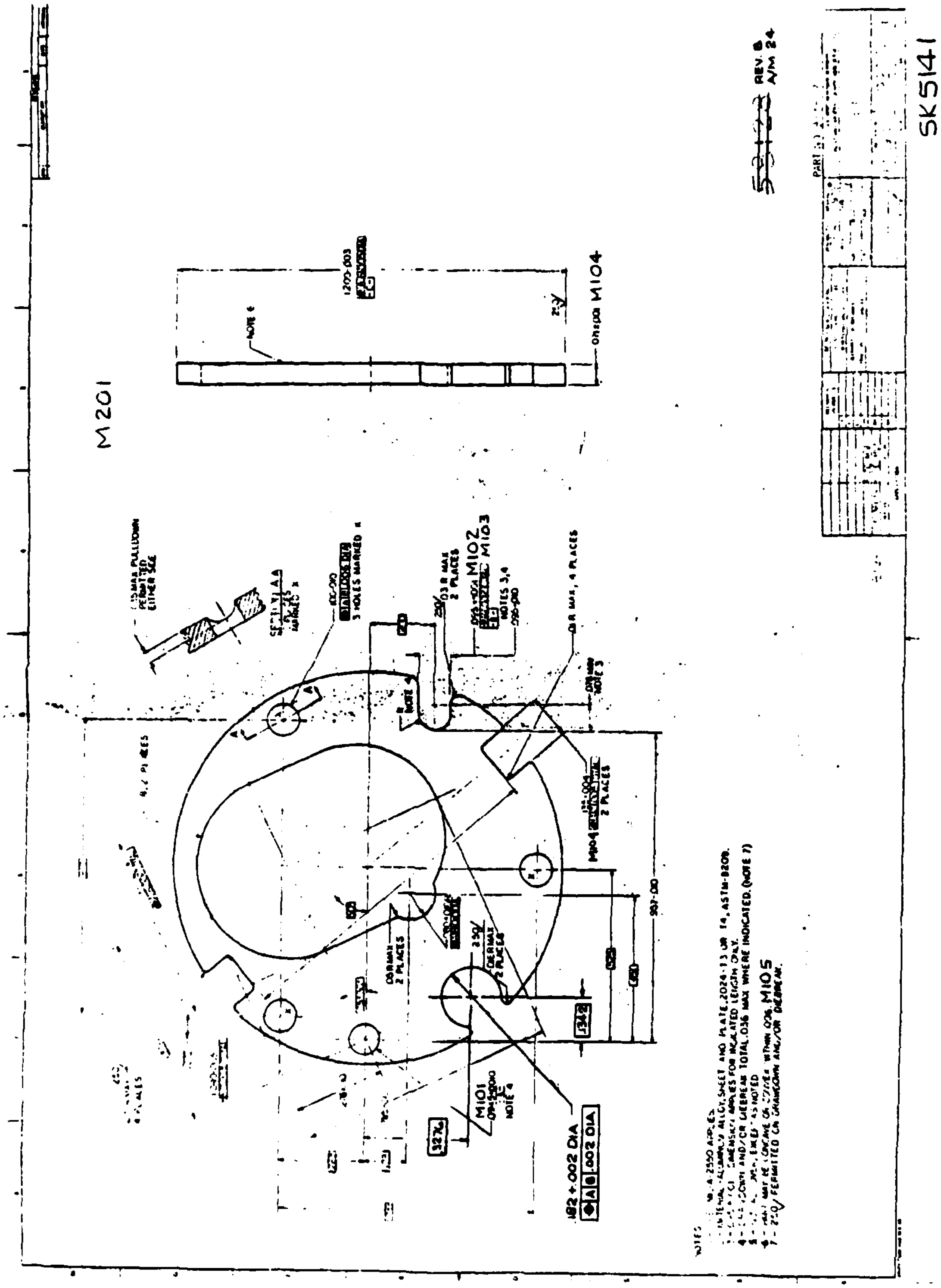

-E-
5986
.182+.003 DIA
.003 DIA
.280±.005 DIA
.010 DIA
97°±1° 2 PLCS
A
.235+.002 - SEE NOTE 2
E F .004 DIA
-R-
(.725)
.3660
(31°26')
(1.425)
(.188)
-F-
.025+.003
.100+.005
.165+.015
.020 R MAX
.003 R MAX
SECTION A-A
NOTES –
1 SEE DRAWING NO. 58107 FOR DIMENSIONS NOT SHOWN.
2 PART IS SHOWN AS DIE CAST IF PART IS MADE BY MODIFYING 58107, TWO 97° FLATS MAY BE OMITTED (.235+.002 DIA TO BE COMPLETE).
REVISIONS
M577
JRH
3/1/79
TRIGGER SPACER
SYSTEMS DIVISION
HAMILTON WATCH CO.
26992
C
4/1
SK5144

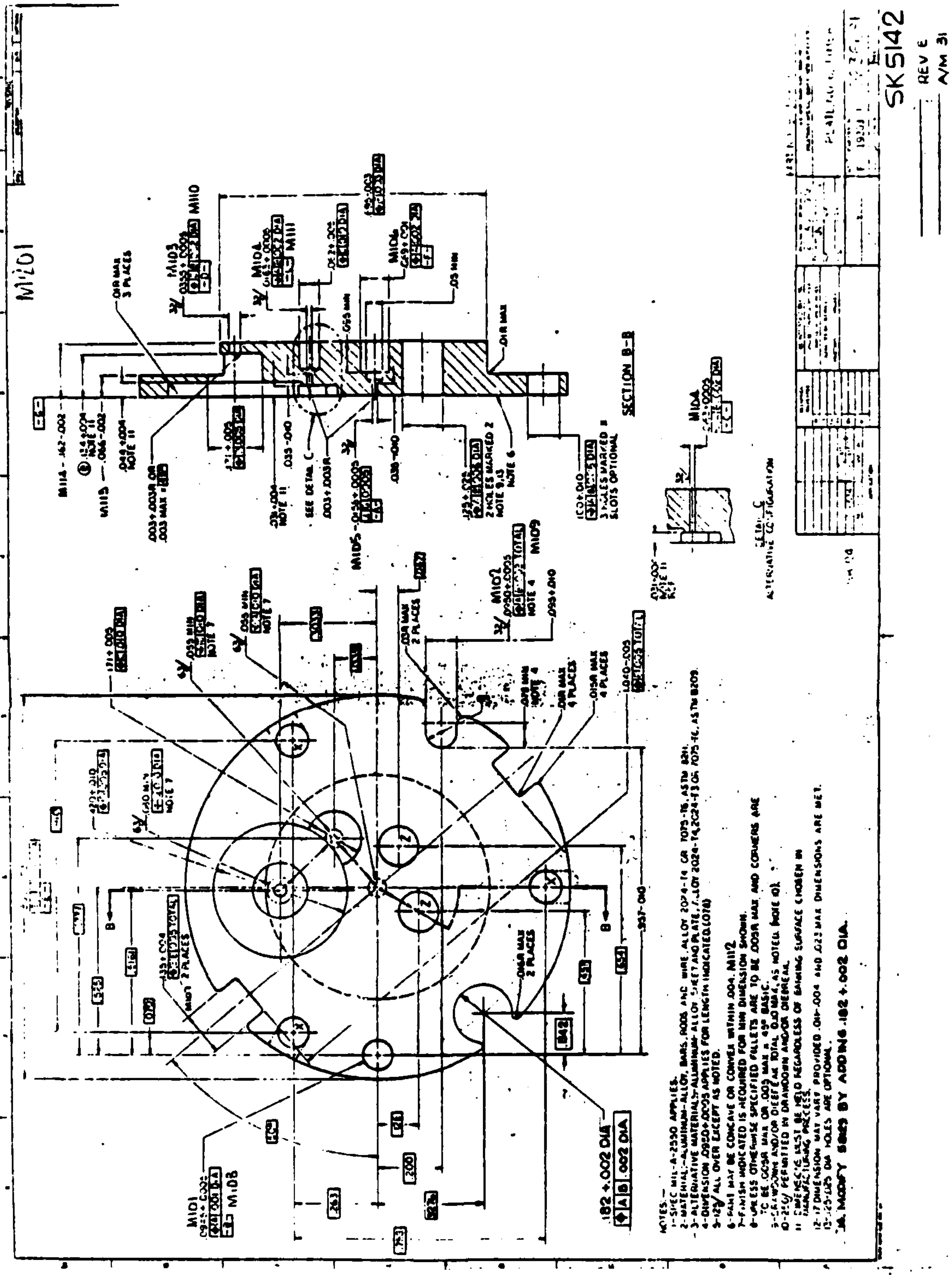

SECTION A-A
PLATE, NO. 1
TIMER
005796


M201
M131
M132
M101
M103
M104
M102
.182 +.002 DIA
SECTION E-E
NOTES —
1- SPEC MIL A-2550 APPLIES.
2-MATERIAL - ALUMINUM ALLOY, SHEET AND PLATE, ALLOY 2024-T3 OR T4, ASTM B209.
5-125/ ALL OVER, EXCEPT AS NOTED.
12-TAB CONFIGURATION INDICATED IS OPTIONAL EXCEPT FOR COMPONENTS TO BE ASSEMBLED ON AUTOMATIC TIMER ASSEMBLY EQUIPMENT.
13. MODIFY 58126 BY ADDING .182+.002 DIA.
58126


M201
1055 - .010
NOTE 8
.060 + .005
.030 + .005 R
.390 + .005
.650 - .005
.140 + .005
NOTE 5
.03 R MAX
TYP NOTE 8
M102
M103
NOTES 3, 4
.095 + .010
R
NOTE 4
.03 R MAX
2 PLACES
R
2 PLACES
.06 R MAX
4 PLACES
.016 R MAX
2 PLACES
.0945 + .001
NOTE 4
.182 + .002 DIA
.002 DIA
.957 - .010
.1342
A
NOTE 6
NOTE 4
.052 - .062
.100 + .010
2 PLACES NOTE 9
.020 - .003
.100 + .010
3 PLACES MARKED x
.025 MAX
EITHER SIDE
SECTION A-A
3 PLACES MARKED x
NOTES: -
1 - SPEC MIL-A-2550 APPLIES.
2 - MATERIAL: - ALUMINUM-ALLOY, SHEET AND PLATE, ALLOY 2024-T3 OR T4, ASTM B209
3 - .095 + .001 DIMENSION APPLIES FOR LENGTH INDICATED.
4 - DRAWDOWN AND/OR DIEBREAK TOTAL .026 MAX WHERE INDICATED. (NOTE 7)
5 - ALL OVER, EXCEPT AS NOTED.
6 - PART MAY BE CONCAVE OR CONVEX WITHIN .005. M104
7 - 250 PERMITTED ON DRAWDOWN AND/OR DIEBREAK.
8 - KEY AUTOMATIC ASSEMBLY DIMENSIONS.
9 - 190 MAX PERMITTED PROVIDED THE REQUIREMENTS FOR TIMER AUTOMATED ASSEMBLY EQUIPMENT ARE MET.
10. MODIFY 58127 BY ADDING 182+.002 DIA.
58127 REV. E
PART NO 923660
22 AUG 1972
PLATE, NO 3, TIMER
19203
923666
SK 5138


M201
M101
M102
M109
M104
M152
M103
M107
M106
M131
M105
.0950 + .0006
.095 + .010
.100 + .010
3 PLACES MARKED X
2 PLACES MARKED W
.188 MAX
1.00 MIN
.016 R MAX 2 PLACES
.03 R MAX 2 PLACES
.078 MIN. NOTE 3
.987 - .010
1342
NOTE 4
NOTE 6
NOTE 9
NOTES 3,4
.002+.003 R OR .002-.003 × 45°
NOTE 10
SECTION D-D
SCALE 20/1
OPTIONAL CONFIGURATION
.005 MAX
.09 MAX
SECTION A-A
SCALE 20/1
NOTES -
1 - SPEC MIL-A-2550 APPLIES.
2 - MATERIAL - ALUMINUM ALLOY SHEET AND PLATE, ALLOY 2024-T3 OR T4, ASTM B209.
3 - .0950 + .0006 DIMENSION APPLIES FOR LENGTH INDICATED.
4 - DRAWDOWN AND/OR DIEBREAK TOTAL .010 MAX WHERE INDICATED (NOTE 7)
5 - ALL OVER EXCEPT AS NOTED.
6 - MAY BE CONCAVE OR CONVEX WITHIN .006 M106
7 - PERMITTED ON DRAWDOWN AND/OR DIEBREAK.
8 - NO DRAWDOWN AND/OR DIEBREAK PERMITTED.
9 - UNLESS OTHERWISE SPECIFIED CORNERS ARE TO BE .008 R MAX OR .008 MAX × 45° BASIC.
10 - AUTOMATIC ASSEMBLY DIMENSIONS.
11 - TAB CONFIGURATION INDICATED IS OPTIONAL EXCEPT FOR COMPONENTS TO BE ASSEMBLED ON AUTOMATIC TIMER ASSEMBLY EQUIPMENT
REV. 1
SK5140


M201
M104
M101
M102
M103
M105
SK5141
REV. B
A/M 24
.182 +.002 DIA



SK5142
REV E
SECTION B-B

APPENDIX B

MODULAR SETBACK PIN

EQUATIONS OF MOTION

M577 Modular Setback Pin

Minimum Velocity Change for Function - Computer Program

Equations from D. L. Overman (Oct. 73)

$$V_{min} = \sum_{i=1}^{f} V_i$$

$$V_i = A\sqrt{\frac{g K_i}{B}} \cos^{-1}\left[1 - \frac{F \quad \Delta x_i}{\frac{A - G_1}{B} - \sum_{i=1}^{i-1} \Delta x_i}\right]$$

$$K_i = 1 + \left(\frac{k}{r}\right)^2 \left[\frac{1 + \mu \tan \alpha_i}{\tan \alpha_i (\tan \alpha_i - \mu)}\right]$$

$$\tan \alpha_i = \frac{L_i}{2\pi r}$$

$$B = \frac{G_2 - G_1}{\sum_{i=1}^{f} \Delta x_i}$$

Variables

DLO	Comp. Prog.		
k	K	radius of gyration	inches
r	R	radius of interaction	inches
L		helix lead	in/turn
	AL	helix lead angle	degrees
μ	MU	coefficient of friction	
G_1	G1	spring bias, safe position	g's
G_2	G2	spring bias, armed position	g's
Δx_i		length of i th leg	inches
	X1	length of first leg	inches
	X2	length of second leg	inches
	X3	length of third leg	inches
A		driving acceleration	g's
	AI	driving acceleration, first iteration	g's
	AF	driving acceleration, final iteration	g's
	I	increment of iteration	g's

$F = 1$ for all legs except final

$$F = \frac{G_2 - .5\ B\Delta X_F}{A}$$

APPENDIX C

MODULAR SETBACK PIN

COMPUTER SIMULATION PROGRAM

APPENDIX C MODULAR SETBACK PIN COMPUTER SIMULATION

```
10 DEF FNACS(X)=ATN(SQR((1-X^2)/X^2))
20 DEF FNNCS(X)=(PI/2-FNACS(X))+PI/2
30 PI=3.141592654#
40 READ K,R,A4,G1,G2,X1,X2,X3,M1,A5,A6,I
50 DATA .0474,.0575,51.14,138,247,.0327,.0654,.0327,.3,300,2000,25
60 INPUT"MU=";M1
70 INPUT "AI=";A5
80 INPUT "AF=";A6
90 INPUT " I=";I
100 PRINT"------------------------"
110 PRINT"     K=";K;"INCH"
120 PRINT"     R=";R;"INCH"
130 PRINT"    AL=";A4;"DEG"
140 PRINT"    MU=";M1;"FRICTION"
150 PRINT"    G1=";G1;"G'S"
160 PRINT"    G2=";G2;"G'S"
170 PRINT"    X1=";X1;"INCH"
180 PRINT"    X2=";X2;"INCH"
190 PRINT"    X3=";X3;"INCH"
200 PRINT"    AI=";A5;"G'S"
210 PRINT"    AF=";A6;"G'S"
220 PRINT"     I=";I;"G'S"
230 PRINT"----------------------------------------"
240 PRINT"SETBACK          TIME  "
250 PRINT" (G'S)           (SEC)"
260 A4=A4*2*PI/360
270 X=TAN(A4)
280 IF M1>X THEN PRINT "TOO MUCH FRICTION"
290 K1=1+(K/R)^2*((1+M1*X)/(X*(X-M1)))
300 S9=X1+X2+X3
310 B=(G2-G1)/S9
320 S8=SQR(386.088*K1/B)
330 F1=1
340 S1=0
350 S2=X1
360 S3=X1+X2
370 FOR A=A5 TO A6 STEP I
380 F3=(G2-.5*B*X3)/A
390 A1=1-F1*X1/((A-G1)/B-S1)
400 A2=1-F1*X2/((A-G1)/B-S2)
410 A3=1-F3*X3/((A-G1)/B-S3)
420 Z1=ABS(A1)
430 Z2=ABS(A2)
440 Z3=ABS(A3)
450 IF Z1>1 OR Z2>1 OR Z3>1 THEN P3=1:GOTO 630
460 IF A1=0 THEN B1=PI/2
470 IF A2=0 THEN B2=PI/2
480 IF A3=0 THEN B3=PI/2
490 IF A1<0 THEN B1=FNNCS(A1)
500 IF A2<0 THEN B2=FNNCS(A2)
510 IF A3<0 THEN B3=FNNCS(A3)
520 IF A1>0 THEN B1=FNACS(A1)
530 IF A2>0 THEN B2=FNACS(A2)
540 IF A3>0 THEN B3=FNACS(A3)
550 V1=A*S8*B1
560 V2=A*S8*B2
570 V3=A*S8*B3
580 V=(V1+V2+V3)/12
590 IF A=A5 THEN V9=V
600 IF V<V9 THEN V9=V:H=1
610 IF V>V9 AND H=1 THEN H=2
620 T=V/(A*32.174)
630 IF P3=1 THEN PRINT A;"      PIN WILL NOT ARM WITH GIVEN DATA"
640 IF P3=0 THEN PRINT A,V,T
650 P3=0
660 NEXT A
670 PRINT"----------------------------------------"
680 D9=.5*V9^2/32.174
690 IF H=2 THEN PRINT"MAX SAFE DROP HEIGHT=";D9;"FT"
700 IF H<>2 THEN PRINT"INSUFFICIENT RANGE TO DETERMINE MAX SAFE DROP HEIGHT"
710 END
```

APPENDIX D

EVALUATION OF COMPUTER SIMULATION PARAMETERS

Appendix D
Evaluation of Parameters used in Computer Program

Radius of gyration is defined by:

$$I = K^2 M$$

and

$$I = \int r^2 \, dm$$

where

I = moment of inertia
K = radius of gyration
M = mass of pin
dm = element of mass
r = distance from axis to element of mass

The moment of inertia of a complex body can be computed by breaking it into smaller bodies and adding the moments of inertia of its components, thus:

$$I = \Sigma I_i$$

The pin is divided into the following component bodies:

1. Main cylinder

2. Internal cylinder

3. Screwdriver slot

4. Entry groove

5. Circumferential groove

6. Zig-zag groove

7. Bottom groove

The moment of inertia of each is computed by:

1. Main cylinder

$$I_1 = 1/2\ M\ r^2$$

$$M_1 = \rho\ \pi\ r^2\ \ell$$

where:

r = radius of cylinder .0675 in.
ℓ = length of cylinder .187 in.
ρ = density of zinc (experimentally determined) .22 lb./in.^{3}
$I_1 = 1.341 \times 10^{-6}$ lb. in.^{2}
$M_1 = 5.889 \times 10^{-4}$ lb.

2. Internal cylinder

r = .032 in.
ℓ = .167 in.
$M_2 = 1.182 \times 10^{-4}$ lb.
$I_2 = 6.052 \times 10^{-8}$ lb. in.^{2}

3. Screwdriver slot

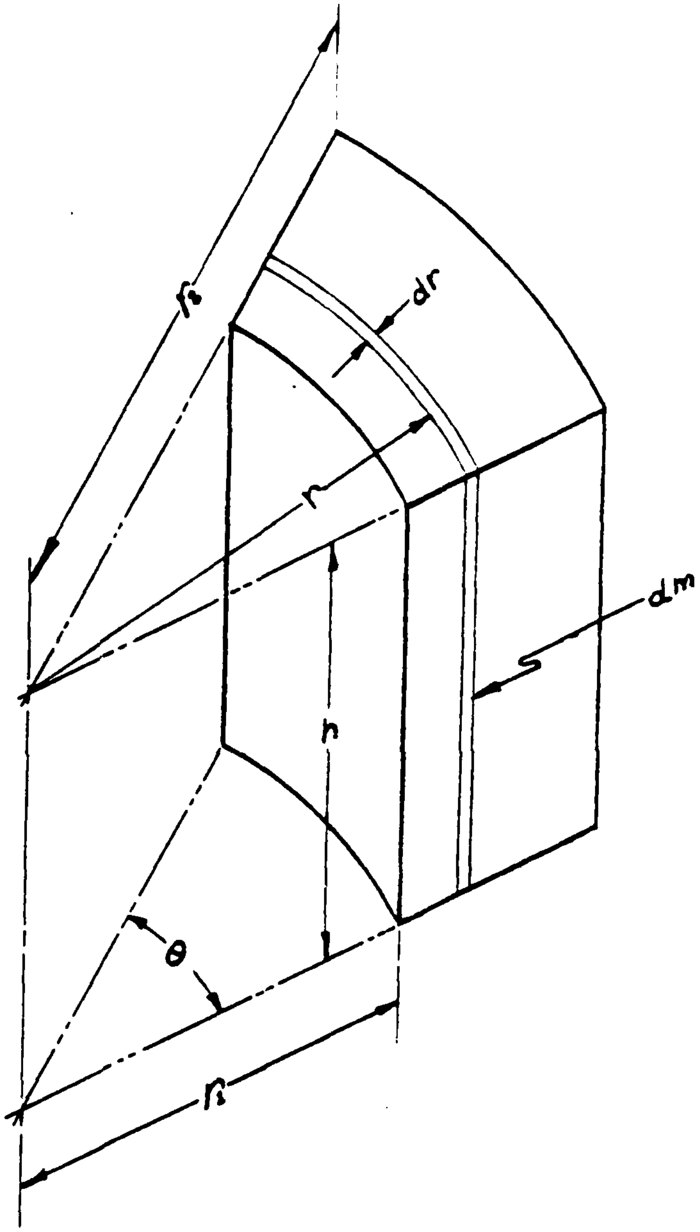
$$M_3 = \rho 2 \ell h b$$

$$I_3 = M\left(\frac{\ell^2}{3} \quad \frac{h^2}{12} \right)$$

ℓ =	half of slot length	.0365
h =	width of slot	.020
b =	height of slot	.020

$M_3 = 6.424 \times 10^{-6}$ lb.
$I_3 = 3.067 \times 10^{-9}$ lb. in.^{2}

4. Entry groove



$I_4 = \int r^2 \, dm$

$M_4 = \int dm$

$dm = \rho r \theta h \, dr$

$M_4 = \rho \theta h \int r \, dr$

$I_4 = \rho \theta \eta \int r^3 \, dr$

$M_4 = 1/2 \, \rho \theta h \quad r_2^{\,2} - r_1^{\,2}$

$I_4 = 1/4 \, \rho \theta h \quad r_2^{\,4} - r_1^{\,4}$

dm = element of mass

r = radius to dm

dr = thickness of dm

h = height of groove .160 in.

θ = angle subtended by groove .945 radians

r_1 = inside radius of groove .048 in.

r_2 = outside radius of groove .068 in.

M_4 = 3.858×10^{-5} lb.

I_4 = 1.337×10^{-7} lb. in.^{2}

5. Circumferential groove

$$M_5 = 1/2\ \rho\theta h\ \ r_2^{\,4} - r_1^{\,2}$$

$$I_5 = 1/4\ \rho\theta h\ \ r_2^{\,4} - r_1^{\,4}$$

θ = 2.466 radians

h = .055 in.

M_5 = 3.461×10^{-5} lb.

I_5 = 1.199×10^{-7} lb. in.^{2}

6. Zig-zag groove

$$M_6 = 1/2\ \rho\theta h\ \ r_2^{\,2} - r_1^{\,2}$$

$$I_6 = 1/4\ \rho\theta h\ \ r_2^{\,4} - r_1^{\,4}$$

θ = .917 radians

h = .187 in.

M_6 = 4.376×10^{-5} lb.

I_6 = 1.516×10^{-7} lb. in.^{2}

7. Bottom groove

$$M_7 = \rho\pi h\ (r_2^{\,2} - r_1^{\,2})$$

$$I_7 = 1/2\ M_7\ (r_2^{\,2} + r_1^{\,2})$$

h = .0075 in.

r_1 = .063 in.

r_2 = .068 in.

M_7 = 3.395×10^{-6} lb.

I_7 = 1.458×10^{-8} lb. in.^{2}

The total mass is:

$$M = M_1 - M_2 - M_3 - M_4 - M_5 - M_6 - M_7$$

$$M = 3.439 \times 10^{-4} \text{ lb.}$$

The total moment of inertia is:

$$I = I_1 - I_2 - I_3 - I_4 - I_5 - I_6 - I_7$$

$$I = 8.576 \times 10^{-7} \text{ lb. in.}^2$$

The radius of gyration, k, is determined by:

$$K = \left(\frac{I}{M}\right)^{1/2}$$

$$K = .0499 \text{ in.}$$

Radius of interaction

The radius of interaction is approximated as occurring at half of the depth of the groove, or .058 inches.

Helix Lead Angle

The helix lead angle is taken at the radius of interaction.

$AL = \tan^{-1} (a/c)$

where:

AL = helix lead angle

a = axial displacement = .0654 in. for second leg

c = circumferential displacement = .0532 in. at .058 in. radius

$AL = 50.87^{\circ}$, or .888 radians

Spring forces

The spring is specified as:

.119 lb. at .296 in.
.228 lb. at .164 in.

The spring rate is therefore:

$R = -.8258$ lb./in.

and the spring equation is:

$F = -.8258 L + .3634$

Starting and finishing spring lengths are:

$L_1 = .2986$ in.

$L_2 = .1715$ in.

So starting and finishing spring forces are:

$F_1 = .1168$ lb.

$F_2 = .2218$ lb.

Since the pin weight was determined to be 3.341×10^{-4} lb, the starting and finishing loads in g's are:

$$G_1 = 350 \text{ g}$$

$$G_2 = 664 \text{ g}$$

APPENDIX E

SETBACK MAGNITUDE

VERSUS

TIME REQUIRED FOR

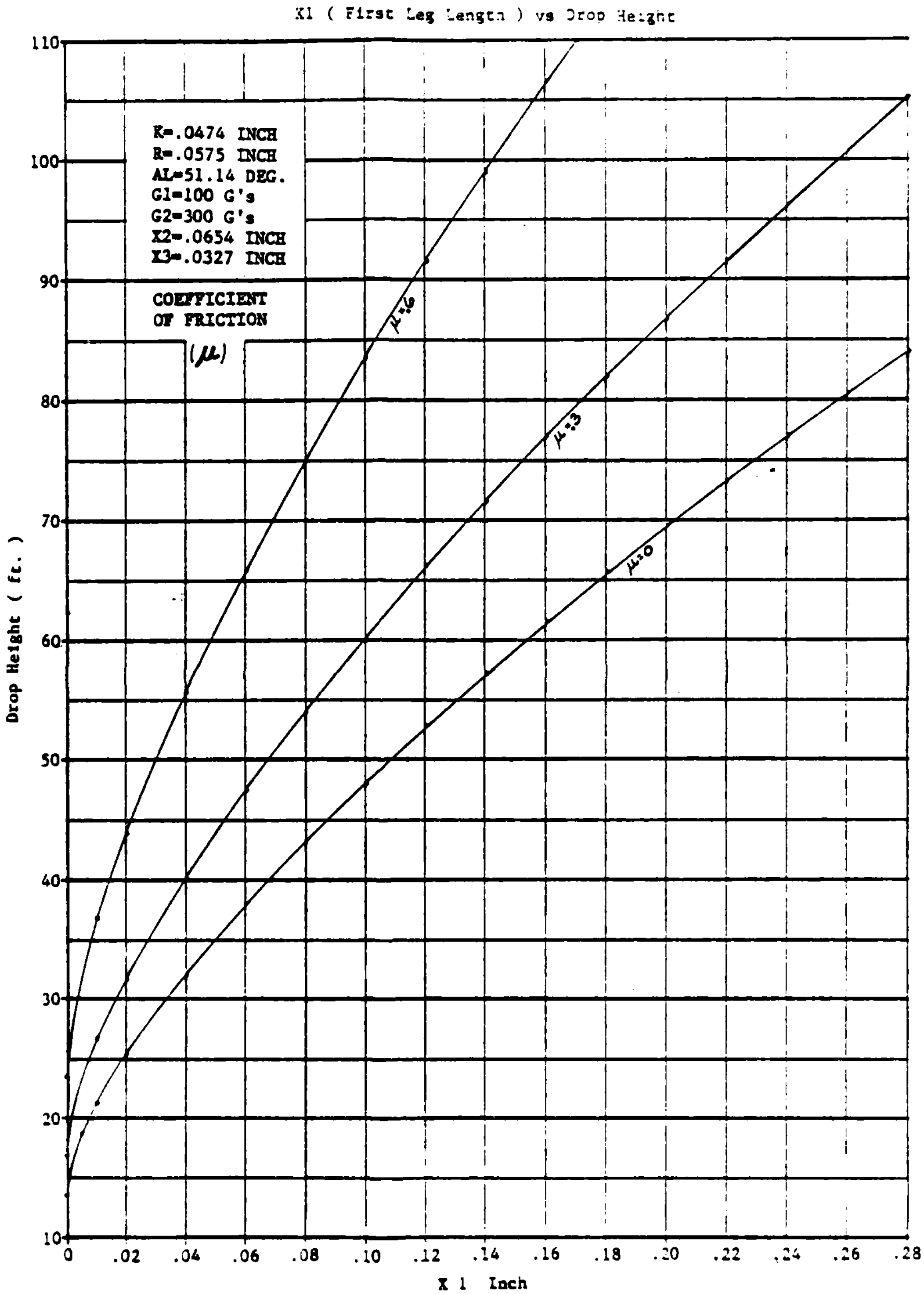
MSP TO FUNCTION

```
*************************
     K= .0474 INCH
     R= .0575 INCH
    AL= 51.14 DEG
    MU= .3 FRICTION
    G1= 138 G'S
    G2= 247 G'S
    X1= .0327 INCH
    X2= .0654 INCH
    X3= .0327 INCH
    AI= 300 G'S
    AF= 30000 G'S
     I= 100 G'S
*************************
```

SETBACK (G'S)	TIME (SEC)
300	5.35554E-03
400	3.7323E-03
500	3.00636E-03
600	2.57217E-03
700	2.27655E-03
800	2.0594E-03
900	1.8916E-03
1000	1.75717E-03
1100	1.64651E-03
1200	1.55344E-03
1300	1.47383E-03
1400	1.40476E-03
1500	1.34413E-03
1600	1.29039E-03
1700	1.24233E-03
1800	1.19904E-03
1900	1.15979E-03
2000	1.124E-03
2100	1.09118E-03
2200	1.06098E-03
2300	1.03305E-03
2400	1.00713E-03
2500	9.82989E-04
2600	9.60449E-04
2700	9.39324E-04
2800	9.19481E-04
2900	9.00805E-04
3000	8.83177E-04
3100	8.66507E-04
3200	8.5072E-04
3300	8.35747E-04
3400	8.21492E-04
3500	8.07917E-04
3600	7.94983E-04
3700	7.82626E-04
3800	7.70804E-04
3900	7.59487E-04
4000	7.48659E-04
4100	7.38247E-04
4200	7.2824E-04
4300	7.18626E-04
4400	7.09367E-04
4500	7.00435E-04
4600	6.91834E-04
4700	6.83546E-04
4800	6.75528E-04
4900	6.67769E-04
5000	6.60269E-04
5100	6.53001E-04
5200	6.45962E-04
5300	6.39177E-04
5400	6.32566E-04
5500	6.26131E-04
5600	6.19908E-04
5700	6.13874E-04
5800	6.07982E-04
5900	6.02244E-04
6000	5.96703E-04
6100	5.91275E-04
6200	5.85985E-04
6300	5.80856E-04
6400	5.75818E-04
6500	5.70943E-04
6600	5.66148E-04
6700	5.61523E-04
6800	5.56992E-04
6900	5.52551E-04
7000	5.48217E-04
7100	5.43967E-04
7200	5.39813E-04
7300	5.35765E-04
7400	5.3179E-04
7500	5.27912E-04
7600	5.24144E-04
7700	5.20378E-04
7800	5.16753E-04
7900	5.13195E-04
8000	5.09683E-04
8100	5.0623E-04
8200	5.02911E-04
8300	4.99587E-04
8400	4.9636E-04
8500	4.93139E-04
8600	4.90053E-04
8700	4.87001E-04
8800	4.83999E-04
8900	4.81038E-04
9000	4.78158E-04
9100	4.75291E-04
9200	4.72476E-04
9300	4.6971E-04
9400	4.67049E-04
9500	4.64398E-04
9600	4.61736E-04
9700	4.59214E-04
9800	4.56678E-04
9900	4.54158E-04
10000	4.51724E-04
10100	4.49287E-04
10200	4.46912E-04
10300	4.44576E-04
10400	4.42264E-04
10500	4.40036E-04
10600	4.37769E-04
10700	4.35581E-04
10800	4.33388E-04
10900	4.31264E-04
11000	4.29144E-04
11100	4.27063E-04
11200	4.25011E-04
11300	4.23023E-04
11400	4.21024E-04
11500	4.19098E-04
11600	4.17118E-04
11700	4.15225E-04
11800	4.13293E-04
11900	4.11454E-04
12000	4.09625E-04
12100	4.07808E-04
12200	4.06026E-04
12300	4.04254E-04
12400	4.02488E-04
12500	4.00756E-04
12600	3.99108E-04
12700	3.97379E-04
12800	3.95776E-04
12900	3.94104E-04
13000	3.92503E-04
13100	3.90876E-04
13200	3.89312E-04
13300	3.87757E-04
13400	3.86249E-04
13500	3.84659E-04
13600	3.83166E-04
13700	3.8167E-04
13800	3.80201E-04
13900	3.7875E-04
14000	3.77308E-04
14100	3.75862E-04
14200	3.74461E-04
14300	3.73052E-04
14400	3.71724E-04
14500	3.70351E-04
14600	3.68969E-04
14700	3.67615E-04
14800	3.66343E-04
14900	3.65009E-04
15000	3.6375E-04
15100	3.6244E-04
15200	3.61219E-04
15300	3.59926E-04
15400	3.58721E-04
15500	3.57441E-04
15600	3.56269E-04
15700	3.55E-04
15800	3.53843E-04
15900	3.52616E-04
16000	3.51477E-04
16100	3.50335E-04
16200	3.49198E-04
16300	3.48084E-04
16400	3.47002E-04
16500	3.45801E-04
16600	3.4471E-04
16700	3.43634E-04
16800	3.42568E-04
16900	3.41506E-04
17000	3.40428E-04
17100	3.39296E-04
17200	3.38263E-04
17300	3.37237E-04
17400	3.36212E-04
17500	3.35195E-04
17600	3.3427E-04
17700	3.33274E-04
17800	3.32258E-04
17900	3.3128E-04
18000	3.30326E-04
18100	3.29327E-04
18200	3.28365E-04
18300	3.27412E-04
18400	3.26464E-04
18500	3.25525E-04
18600	3.24669E-04
18700	3.23742E-04
18800	3.22787E-04
18900	3.21886E-04
19000	3.20955E-04
19100	3.20053E-04
19200	3.19243E-04
19300	3.18354E-04
19400	3.17461E-04
19500	3.16679E-04
19600	3.15789E-04
19700	3.15024E-04
19800	3.14153E-04
19900	3.13267E-04
20000	3.12403E-04
20100	3.11655E-04
20200	3.10814E-04
20300	3.09994E-04
20400	3.09257E-04
20500	3.08402E-04
20600	3.07678E-04
20700	3.06861E-04
20800	3.06018E-04
20900	3.05307E-04
21000	3.04525E-04
21100	3.03831E-04
21200	3.03029E-04
21300	3.02238E-04
21400	3.01547E-04
21500	3.00728E-04
21600	3.00065E-04
21700	2.99278E-04
21800	2.98632E-04
21900	2.97858E-04
22000	2.97204E-04
22100	2.96441E-04
22200	2.95796E-04
22300	2.95044E-04
22400	2.94404E-04
22500	2.93769E-04
22600	2.93026E-04
22700	2.924E-04
22800	2.91664E-04
22900	2.91049E-04
23000	2.90294E-04
23100	2.89682E-04
23200	2.89077E-04
23300	2.88368E-04
23400	2.87768E-04
23500	2.87053E-04
23600	2.86465E-04
23700	2.85754E-04
23800	2.85183E-04
23900	2.84597E-04
24000	2.83913E-04
24100	2.83336E-04
24200	2.82647E-04
24300	2.8208E-04
24400	2.81525E-04
24500	2.80811E-04
24600	2.80267E-04
24700	2.79705E-04
24800	2.79044E-04
24900	2.78501E-04
25000	2.77962E-04
25100	2.77328E-04
25200	2.7679E-04
25300	2.76257E-04
25400	2.7561E-04
25500	2.75087E-04
25600	2.74551E-04
25700	2.73879E-04
25800	2.73364E-04
25900	2.72860E-04
26000	2.72216E-04
26100	2.71707E-04
26200	2.71212E-04
26300	2.70575E-04
26400	2.70087E-04
26500	2.69595E-04
26600	2.69087E-04
26700	2.68458E-04
26800	2.67979E-04
26900	2.67492E-04
27000	2.67014E-04
27100	2.6655E-04
27200	2.65921E-04
27300	2.65455E-04
27400	2.64985E-04
27500	2.64514E-04
27600	2.63907E-04
27700	2.63456E-04
27800	2.62983E-04
27900	2.62531E-04
28000	2.61941E-04
28100	2.61496E-04
28200	2.61039E-04
28300	2.60584E-04
28400	2.5997E-04
28500	2.59516E-04
28600	2.59089E-04
28700	2.58639E-04
28800	2.58055E-04
28900	2.57629E-04
29000	2.57208E-04
29100	2.56767E-04
29200	2.56339E-04
29300	2.55771E-04
29400	2.55347E-04
29500	2.54925E-04
29600	2.54503E-04
29700	2.53939E-04
29800	2.53538E-04
29900	2.53114E-04
30000	2.52697E-04

APPENDIX F

A RELATIVE COMPARISON OF NINE DESIGN FEATURES AS THEY RELATE TO DROP HEIGHT


X1 (First Leg Length) vs Drop Height
K=.0474 INCH
R=.0575 INCH
AL=51.14 DEG.
G1=100 G's
G2=300 G's
X2=.0654 INCH
X3=.0327 INCH
COEFFICIENT
OF FRICTION
(μ)
μ=.6
μ=.3
μ=0
Drop Height (ft.)
X 1 Inch
110
100
90
80
70
60
50
40
30
20
10
0
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
.24
.26
.28

```
*********************************************
  K= .0474 INCH
  H= .0575 INCH
 AL= 51.14 DEG
 MU= 0 FRICTION
 G1= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 A1= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
*********************************************
```

(X1) (IN)	DROP HEIGHT (FT)		
0.000	13.683	0.155	60.611
0.005	18.829	0.160	61.650
0.010	21.416	0.165	62.680
0.015	23.592	0.170	63.699
0.020	25.555	0.175	64.710
0.025	27.378	0.180	65.712
0.030	29.100	0.185	66.705
0.035	30.743	0.190	67.691
0.040	32.322	0.195	68.668
0.045	33.846	0.200	69.638
0.050	35.324	0.205	70.601
0.055	36.761	0.210	71.556
0.060	38.162	0.215	72.505
0.065	39.529	0.220	73.447
0.070	40.867	0.225	74.383
0.075	42.177	0.230	75.312
0.080	43.463	0.235	76.236
0.085	44.725	0.240	77.153
0.090	45.965	0.245	78.065
0.095	47.185	0.250	78.971
0.100	48.386	0.255	79.872
0.105	49.570	0.260	80.768
0.110	50.736	0.265	81.659
0.115	51.887	0.270	82.544
0.120	53.023	0.275	83.425
0.125	54.144	0.280	84.301
0.130	55.252	0.285	85.173
0.135	56.348	0.290	86.040
0.140	57.431	0.295	86.903
0.145	58.502	0.300	87.761
0.150	59.562		

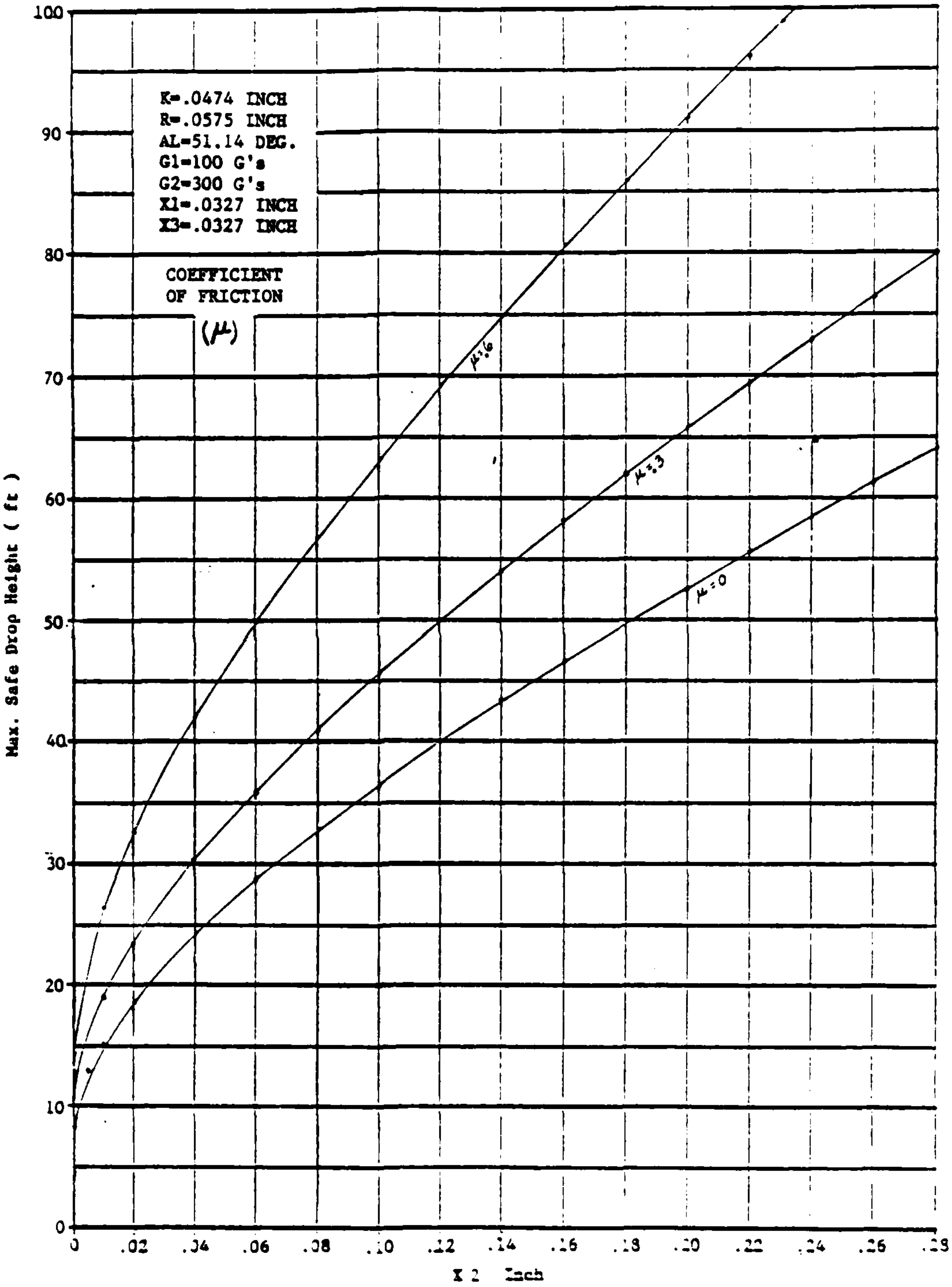
```
**********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= .3 FRICTION
 G1= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 A1= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
**********************************************
```

(X1) (IN)	DROP HEIGHT (FT)
0.000	17.076
0.005	23.496
0.010	26.725
0.015	29.441
0.020	31.890
0.025	34.165
0.030	36.314
0.035	38.364
0.040	40.334
0.045	42.237
0.050	44.081
0.055	45.874
0.060	47.622
0.065	49.329
0.070	50.998
0.075	52.633
0.080	54.237
0.085	55.812
0.090	57.360
0.095	58.882
0.100	60.381
0.105	61.858
0.110	63.314
0.115	64.750
0.120	66.167
0.125	67.567
0.130	68.949
0.135	70.316
0.140	71.668
0.145	73.004
0.150	74.327
0.155	75.637
0.160	76.933
0.165	78.218
0.170	79.490
0.175	80.752
0.180	82.002
0.185	83.242
0.190	84.471
0.195	85.691
0.200	86.902
0.205	88.103
0.210	89.295
0.215	90.479
0.220	91.655
0.225	92.822
0.230	93.982
0.235	95.134
0.240	96.280
0.245	97.417
0.250	98.549
0.255	99.673
0.260	100.790
0.265	101.902
0.270	103.007
0.275	104.106
0.280	105.200
0.285	106.287
0.290	107.369
0.295	108.446
0.300	109.517

****
K= .0474 INCH
R= .0575 INCH
AL= 51.14 DEG
MU= .6 FRICTION
G1= 100 G'S
G2= 300 G'S
X1= .0327 INCH
X2= .0654 INCH
X3= .0327 INCH
A1= 301 G'S
AF= 2000 G'S
I= 1 G'S
****

(X1) (IN)	DROP HEIGHT (FT)
0.000	23.641
0.005	32.533
0.010	37.003
0.015	40.763
0.020	44.154
0.025	47.304
0.030	50.279
0.035	53.118
0.040	55.846
0.045	58.480
0.050	61.034
0.055	63.516
0.060	65.936
0.065	68.299
0.070	70.610
0.075	72.875
0.080	75.095
0.085	77.276
0.090	79.419
0.095	81.527
0.100	83.602
0.105	85.647
0.110	87.663
0.115	89.651
0.120	91.613
0.125	93.551
0.130	95.466
0.135	97.358
0.140	99.229
0.145	101.080
0.150	102.912
0.155	104.725
0.160	106.520
0.165	108.298
0.170	110.060
0.175	111.806
0.180	113.538
0.185	115.254
0.190	116.957
0.195	118.646
0.200	120.322
0.205	121.985
0.210	123.636
0.215	125.275
0.220	126.903
0.225	128.519
0.230	130.125
0.235	131.721
0.240	133.306
0.245	134.882
0.250	136.448
0.255	138.004
0.260	139.552
0.265	141.091
0.270	142.621
0.275	144.143
0.280	145.657
0.285	147.163
0.290	148.661
0.295	150.152
0.300	151.635

Drop Height vs X2 (Second Leg)



****
K= .0474 INCH
R= .0575 INCH
AL= 51.14 DEG
MU= 0 FRICTION
G1= 100 G'S
G2= 300 G'S
X1= .0327 INCH
X2= .0654 INCH
X3= .0327 INCH
A1= 301 G'S
AF= 2000 G'S
I= 1 G'S
****

(X2) (IN)	DROP HEIGHT (FT)
0.000	8.401
0.005	13.078
0.010	15.351
0.015	17.213
0.020	18.855
0.025	20.354
0.030	21.748
0.035	23.063
0.040	24.314
0.045	25.512
0.050	26.665
0.055	27.780
0.060	28.861
0.065	29.913
0.070	30.938
0.075	31.940
0.080	32.921
0.085	33.882
0.090	34.825
0.095	35.752
0.100	36.664
0.105	37.562
0.110	38.446
0.115	39.319
0.120	40.180
0.125	41.031
0.130	41.872
0.135	42.703
0.140	43.525
0.145	44.339
0.150	45.144
0.155	45.942
0.160	46.733
0.165	47.517
0.170	48.294
0.175	49.065
0.180	49.830
0.185	50.589
0.190	51.342
0.195	52.091
0.200	52.833
0.205	53.571
0.210	54.305
0.215	55.033
0.220	55.758
0.225	56.478
0.230	57.193
0.235	57.905
0.240	58.613
0.245	59.317
0.250	60.018
0.255	60.715
0.260	61.409
0.265	62.099
0.270	62.786
0.275	63.470
0.280	64.151
0.285	64.829
0.290	65.504
0.295	66.176
0.300	66.846

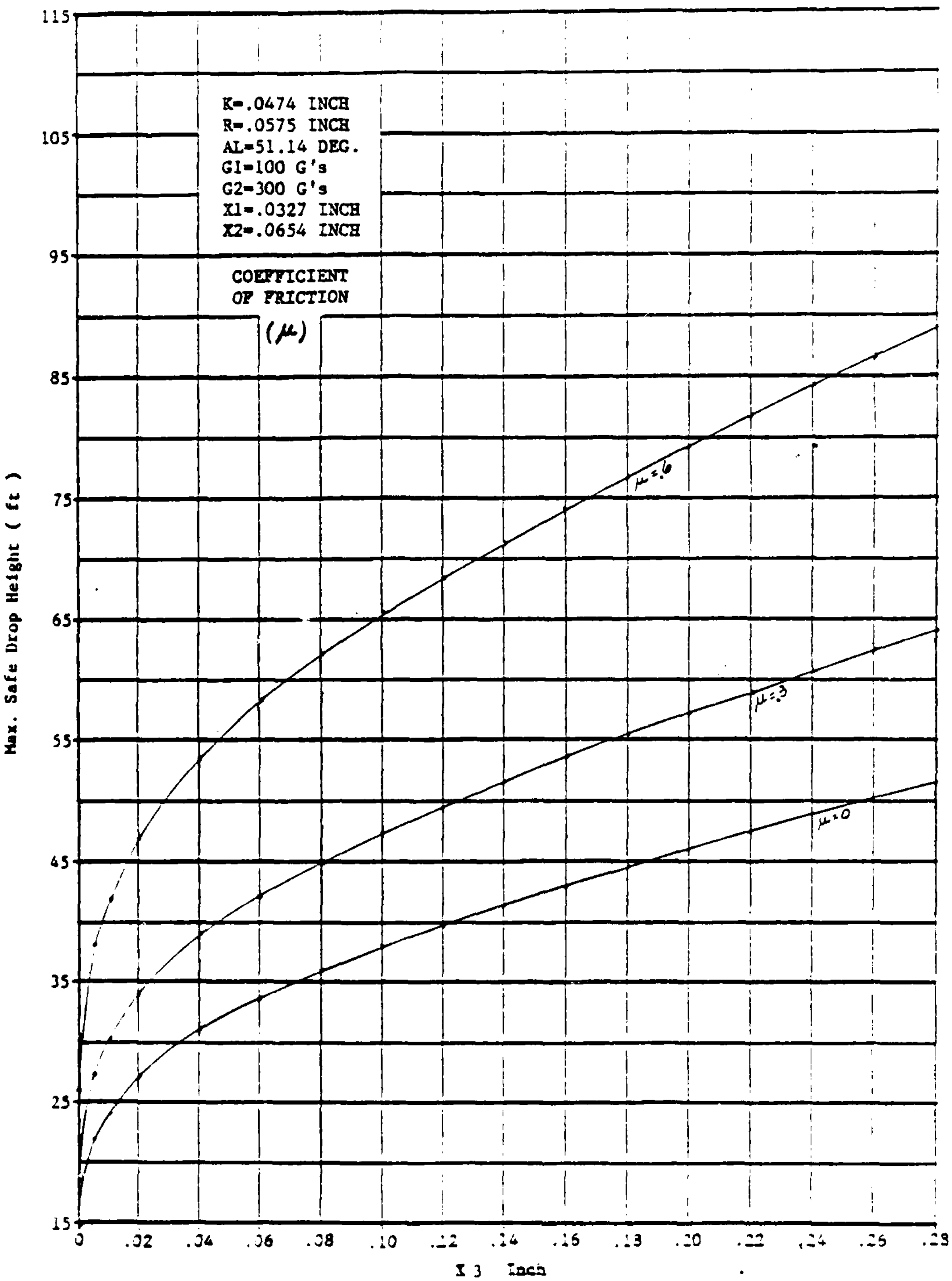
```
**********************************************
   K= .0474 INCH
   R= .0575 INCH
  AL= 51.14 DEG
  MU= .3 FRICTION
  G1= 100 G'S
  G2= 300 G'S
  X1= .0327 INCH
  X2= .0654 INCH
  X3= .0327 INCH
  A1= 301 G'S
  AF= 2000 G'S
   I= 1 G'S
**********************************************
```

(X2) (IN)	DROP HEIGHT (FT)	(X2) (IN)	DROP HEIGHT (FT)
0.000	10.484	0.155	57.331
0.005	16.320	0.160	58.318
0.010	19.157	0.165	59.296
0.015	21.480	0.170	60.266
0.020	23.529	0.175	61.228
0.025	25.399	0.180	62.183
0.030	27.140	0.185	63.130
0.035	28.781	0.190	64.070
0.040	30.341	0.195	65.004
0.045	31.836	0.200	65.931
0.050	33.275	0.205	66.852
0.055	34.666	0.210	67.767
0.060	36.016	0.215	68.676
0.065	37.328	0.220	69.580
0.070	38.608	0.225	70.478
0.075	39.858	0.230	71.372
0.080	41.082	0.235	72.260
0.085	42.281	0.240	73.143
0.090	43.458	0.245	74.022
0.095	44.615	0.250	74.896
0.100	45.753	0.255	75.766
0.105	46.873	0.260	76.632
0.110	47.977	0.265	77.493
0.115	49.066	0.270	78.351
0.120	50.141	0.275	79.204
0.125	51.203	0.280	80.054
0.130	52.252	0.285	80.900
0.135	53.289	0.290	81.742
0.140	54.315	0.295	82.581
0.145	55.330	0.300	83.417
0.150	56.336		

```
*********************************************
   K= .0474 INCH
   H= .0575 INCH
  AL= 51.14 DEG
  MU= .6 FRICTION
  G1= 100 G'S
  G2= 300 G'S
  X1= .0327 INCH
  X2= .0654 INCH
  X3= .0327 INCH
  A1= 301 G'S
  AF= 2000 G'S
   I= 1 G'S
*********************************************
```

(X2) (IN)	DROP HEIGHT (FT)
0.000	14.616
0.005	22.596
0.010	26.524
0.015	29.741
0.020	32.578
0.025	35.167
0.030	37.577
0.035	39.849
0.040	42.010
0.045	44.080
0.050	46.072
0.055	47.998
0.060	49.866
0.065	51.684
0.070	53.455
0.075	55.186
0.080	56.881
0.085	58.541
0.090	60.171
0.095	61.773
0.100	63.348
0.105	64.899
0.110	66.428
0.115	67.936
0.120	69.424
0.125	70.894
0.130	72.346
0.135	73.782
0.140	75.203
0.145	76.609
0.150	78.001
0.155	79.380
0.160	80.746
0.165	82.100
0.170	83.443
0.175	84.775
0.180	86.096
0.185	87.408
0.190	88.710
0.195	90.003
0.200	91.286
0.205	92.561
0.210	93.828
0.215	95.087
0.220	96.339
0.225	97.583
0.230	98.820
0.235	100.049
0.240	101.273
0.245	102.489
0.250	103.700
0.255	104.904
0.260	106.102
0.265	107.295
0.270	108.482
0.275	109.664
0.280	110.841
0.285	112.012
0.290	113.178
0.295	114.340
0.300	115.497

Drop Height vs X3 (Third Leg)



```
*******************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= 0 FRICTION
 U1= 100 G'S
 U2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 AI= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
*******************************************
```

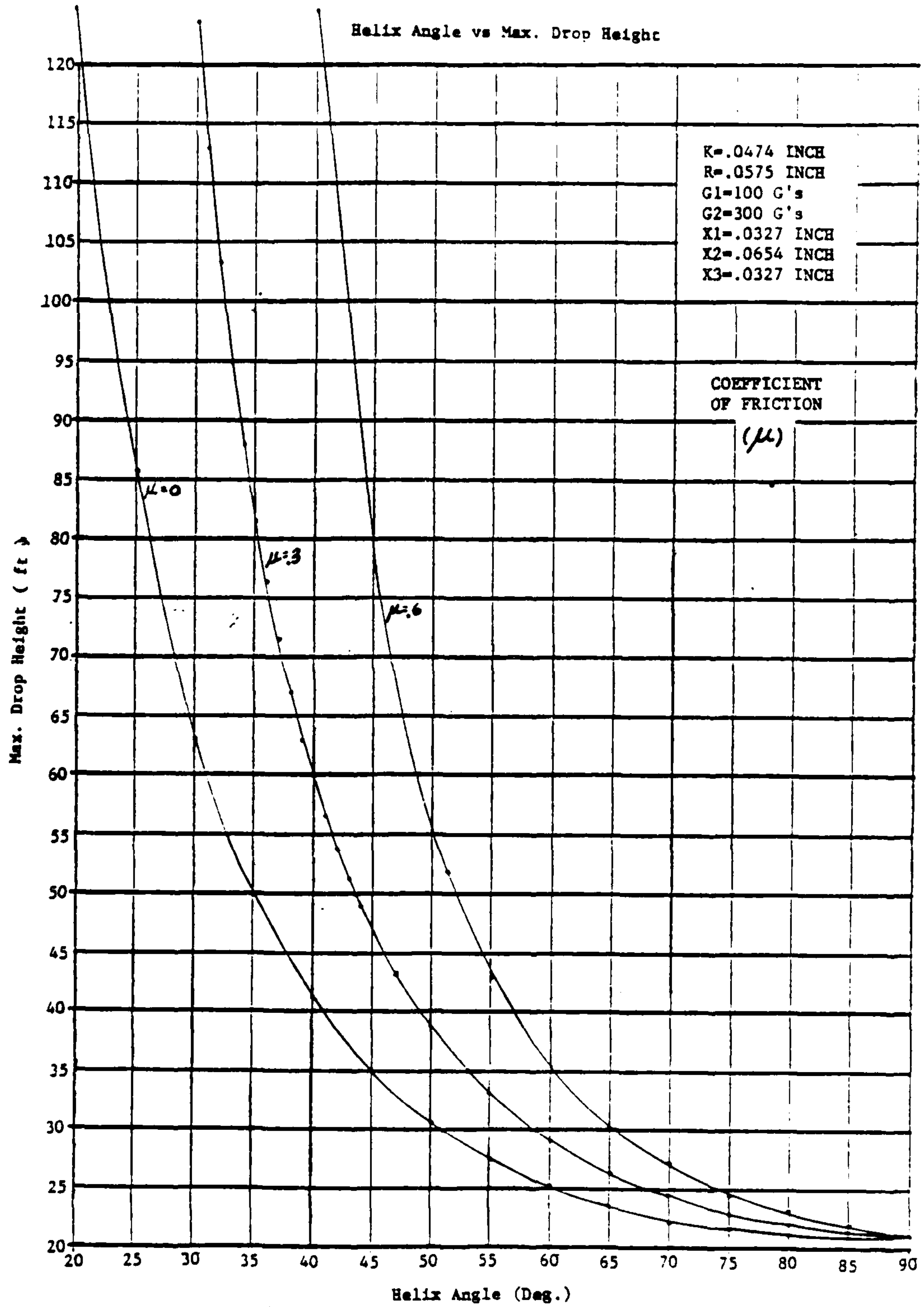
(X3) (IN)	DROP HEIGHT (FT)
0.000	15.046
0.005	21.978
0.010	24.358
0.015	26.048
0.020	27.393
0.025	28.524
0.030	29.510
0.035	30.389
0.040	31.188
0.045	31.924
0.050	32.610
0.055	33.254
0.060	33.865
0.065	34.446
0.070	35.003
0.075	35.540
0.080	36.058
0.085	36.560
0.090	37.048
0.095	37.523
0.100	37.988
0.105	38.442
0.110	38.888
0.115	39.325
0.120	39.755
0.125	40.178
0.130	40.595
0.135	41.006
0.140	41.412
0.145	41.814
0.150	42.210
0.155	42.602
0.160	42.991
0.165	43.375
0.170	43.756
0.175	44.134
0.180	44.509
0.185	44.880
0.190	45.249
0.195	45.615
0.200	45.979
0.205	46.340
0.210	46.699
0.215	47.056
0.220	47.410
0.225	47.763
0.230	48.114
0.235	48.462
0.240	48.809
0.245	49.154
0.250	49.498
0.255	49.840
0.260	50.180
0.265	50.519
0.270	50.856
0.275	51.192
0.280	51.526
0.285	51.859
0.290	52.191
0.295	52.521
0.300	52.851

```
*********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= .3 FRICTION
 G1= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 A1= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
*********************************************
```

(X3) (IN)	DROP HEIGHT (FT)	(X3) (IN)	DROP HEIGHT (FT)
0.000	18.776	0.155	53.164
0.005	27.422	0.160	53.648
0.010	30.396	0.165	54.128
0.015	32.506	0.170	54.604
0.020	34.184	0.175	55.075
0.025	35.595	0.180	55.542
0.030	36.825	0.185	56.006
0.035	37.923	0.190	56.466
0.040	38.920	0.195	56.923
0.045	39.838	0.200	57.377
0.050	40.694	0.205	57.828
0.055	41.498	0.210	58.276
0.060	42.260	0.215	58.721
0.065	42.986	0.220	59.163
0.070	43.681	0.225	59.603
0.075	44.350	0.230	60.041
0.080	44.996	0.235	60.476
0.085	45.623	0.240	60.909
0.090	46.232	0.245	61.340
0.095	46.825	0.250	61.768
0.100	47.405	0.255	62.195
0.105	47.972	0.260	62.619
0.110	48.528	0.265	63.042
0.115	49.074	0.270	63.463
0.120	49.610	0.275	63.882
0.125	50.138	0.280	64.299
0.130	50.659	0.285	64.715
0.135	51.172	0.290	65.129
0.140	51.679	0.295	65.541
0.145	52.179	0.300	65.952
0.150	52.674		

```
*********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= .6 FRICTION
 G1= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 AI= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
*********************************************
```

(X3) (IN)	DROP HEIGHT (FT)
0.000	25.997
0.005	37.974
0.010	42.085
0.015	45.006
0.020	47.330
0.025	49.284
0.030	50.987
0.035	52.506
0.040	53.887
0.045	55.159
0.050	56.343
0.055	57.457
0.060	58.512
0.065	59.517
0.070	60.479
0.075	61.406
0.080	62.301
0.085	63.168
0.090	64.011
0.095	64.833
0.100	65.635
0.105	66.421
0.110	67.190
0.115	67.946
0.120	68.689
0.125	69.420
0.130	70.141
0.135	70.851
0.140	71.553
0.145	72.246
0.150	72.931
0.155	73.609
0.160	74.280
0.165	74.944
0.170	75.603
0.175	76.255
0.180	76.903
0.185	77.545
0.190	78.182
0.195	78.815
0.200	79.443
0.205	80.067
0.210	80.687
0.215	81.304
0.220	81.916
0.225	82.525
0.230	83.131
0.235	83.734
0.240	84.333
0.245	84.929
0.250	85.523
0.255	86.114
0.260	86.701
0.265	87.287
0.270	87.869
0.275	88.450
0.280	89.027
0.285	89.603
0.290	90.176
0.295	90.747
0.300	91.316


Helix Angle vs Max. Drop Height
K=.0474 INCH
R=.0575 INCH
G1=100 G's
G2=300 G's
X1=.0327 INCH
X2=.0654 INCH
X3=.0327 INCH
COEFFICIENT OF FRICTION
(μ)
μ=0
μ=.3
μ=.6
Max. Drop Height (ft)
Helix Angle (Deg.)
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
20 25 30 35 40 45 50 55 60 65 70 75 80 85 90

```
********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= 0 FRICTION
 G1= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 AI= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
********************************************
```

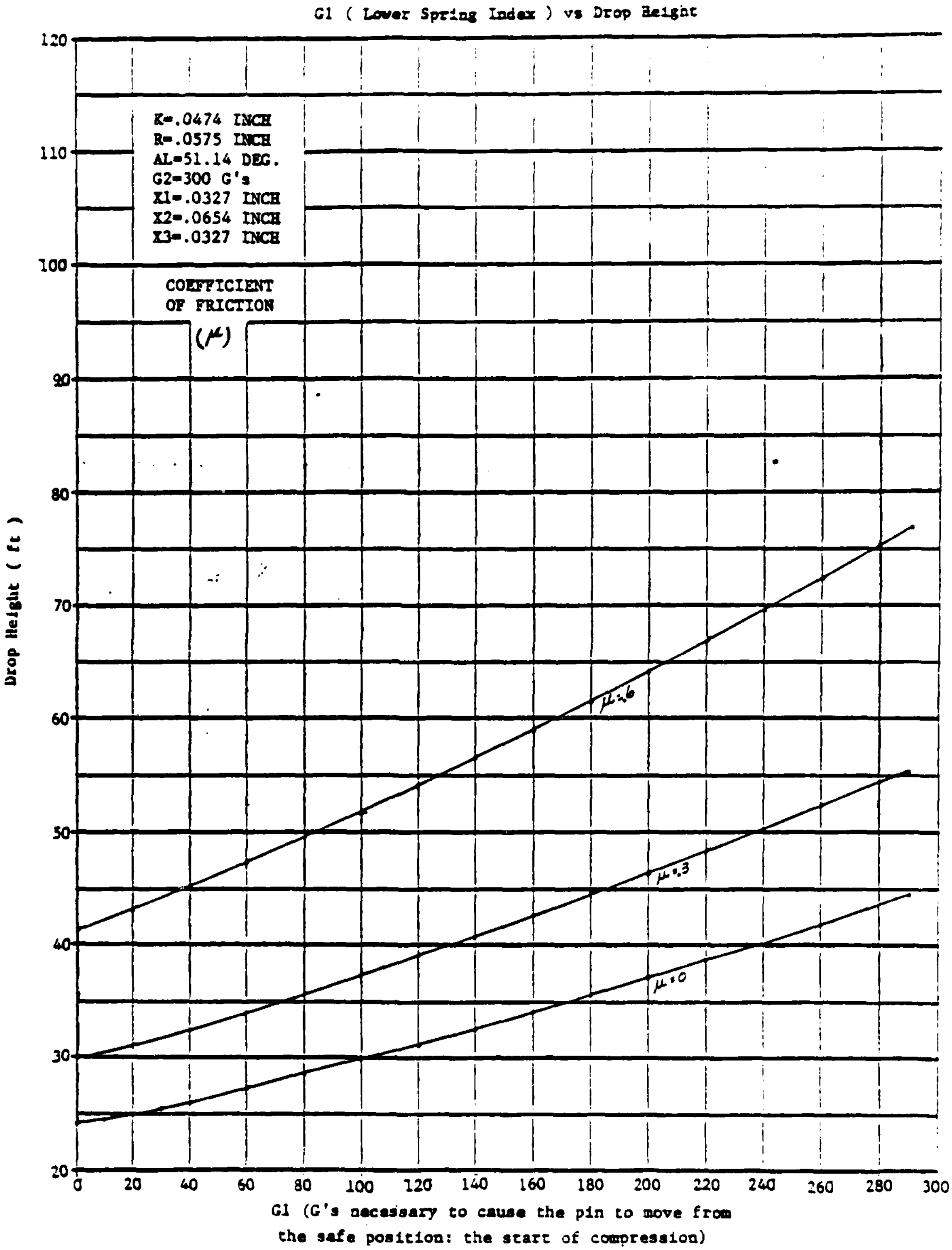
(AL) (DEG)	DROP HEIGHT (FT)
1.000	29.996
2.000	29.996
3.000	29.996
4.000	29.996
5.000	29.996
6.000	29.996
7.000	29.996
8.000	29.996
9.000	29.996
10.000	29.996
11.000	29.996
12.000	29.996
13.000	29.996
14.000	29.996
15.000	29.996
16.000	29.996
17.000	29.996
18.000	29.996
19.000	29.996
20.000	29.996
21.000	29.996
22.000	29.996
23.000	29.996
24.000	29.996
25.000	29.996
26.000	29.996
27.000	29.996
28.000	29.996
29.000	29.996
30.000	29.996
31.000	29.996
32.000	29.996
33.000	29.996
34.000	29.996
35.000	29.996
36.000	29.996
37.000	29.996
38.000	29.996
39.000	29.996
40.000	29.996
41.000	29.996
42.000	29.996
43.000	29.996
44.000	29.996
45.000	29.996
46.000	29.996
47.000	29.996
48.000	29.996
49.000	29.996
50.000	29.996
51.000	29.996
52.000	29.996
53.000	29.996
54.000	29.996
55.000	29.996
56.000	29.996
57.000	29.996
58.000	29.996
59.000	29.996
60.000	29.996
61.000	29.996
62.000	29.996
63.000	29.996
64.000	29.996
65.000	29.996
66.000	29.996
67.000	29.996
68.000	29.996
69.000	29.996
70.000	29.996
71.000	29.996
72.000	29.996
73.000	29.996
74.000	29.996
75.000	29.996
76.000	29.996
77.000	29.996
78.000	29.996
79.000	29.996
80.000	29.996
81.000	29.996
82.000	29.996
83.000	29.996
84.000	29.996
85.000	29.996
86.000	29.996
87.000	29.996
88.000	29.996
89.000	29.996
90.000	29.996

```
********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= .3 FRICTION
 G1= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 A1= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
********************************************
```

(AL) (DEG)	DROP HEIGHT (FT)
1.000	37.432
2.000	37.432
3.000	37.432
4.000	37.432
5.000	37.432
6.000	37.432
7.000	37.432
8.000	37.432
9.000	37.432
10.000	37.432
11.000	37.432
12.000	37.432
13.000	37.432
14.000	37.432
15.000	37.432
16.000	37.432
17.000	37.432
18.000	37.432
19.000	37.432
20.000	37.432
21.000	37.432
22.000	37.432
23.000	37.432
24.000	37.432
25.000	37.432
26.000	37.432
27.000	37.432
28.000	37.432
29.000	37.432
30.000	37.432
31.000	37.432
32.000	37.432
33.000	37.432
34.000	37.432
35.000	37.432
36.000	37.432
37.000	37.432
38.000	37.432
39.000	37.432
40.000	37.432
41.000	37.432
42.000	37.432
43.000	37.432
44.000	37.432
45.000	37.432
46.000	37.432
47.000	37.432
48.000	37.432
49.000	37.432
50.000	37.432
51.000	37.432
52.000	37.432
53.000	37.432
54.000	37.432
55.000	37.432
56.000	37.432
57.000	37.432
58.000	37.432
59.000	37.432
60.000	37.432
61.000	37.432
62.000	37.432
63.000	37.432
64.000	37.432
65.000	37.432
66.000	37.432
67.000	37.432
68.000	37.432
69.000	37.432
70.000	37.432
71.000	37.432
72.000	37.432
73.000	37.432
74.000	37.432
75.000	37.432
76.000	37.432
77.000	37.432
78.000	37.432
79.000	37.432
80.000	37.432
81.000	37.432
82.000	37.432
83.000	37.432
84.000	37.432
85.000	37.432
86.000	37.432
87.000	37.432
88.000	37.432
89.000	37.432
90.000	37.432

```
*********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= .6 FRICTION
 G1= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 A1= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
*********************************************
```

(AL) (DEG)	DROP HEIGHT (FT)		
1.000	51.827	46.000	51.827
2.000	51.827	47.000	51.827
3.000	51.827	48.000	51.827
4.000	51.827	49.000	51.827
5.000	51.827	50.000	51.827
6.000	51.827	51.000	51.827
7.000	51.827	52.000	51.827
8.000	51.827	53.000	51.827
9.000	51.827	54.000	51.827
10.000	51.827	55.000	51.827
11.000	51.827	56.000	51.827
12.000	51.827	57.000	51.827
13.000	51.827	58.000	51.827
14.000	51.827	59.000	51.827
15.000	51.827	60.000	51.827
16.000	51.827	61.000	51.827
17.000	51.827	62.000	51.827
18.000	51.827	63.000	51.827
19.000	51.827	64.000	51.827
20.000	51.827	65.000	51.827
21.000	51.827	66.000	51.827
22.000	51.827	67.000	51.827
23.000	51.827	68.000	51.827
24.000	51.827	69.000	51.827
25.000	51.827	70.000	51.827
26.000	51.827	71.000	51.827
27.000	51.827	72.000	51.827
28.000	51.827	73.000	51.827
29.000	51.827	74.000	51.827
30.000	51.827	75.000	51.827
31.000	51.827	76.000	51.827
32.000	51.827	77.000	51.827
33.000	51.827	78.000	51.827
34.000	51.827	79.000	51.827
35.000	51.827	80.000	51.827
36.000	51.827	81.000	51.827
37.000	51.827	82.000	51.827
38.000	51.827	83.000	51.827
39.000	51.827	84.000	51.827
40.000	51.827	85.000	51.827
41.000	51.827	86.000	51.827
42.000	51.827	87.000	51.827
43.000	51.827	88.000	51.827
44.000	51.827	89.000	51.827
45.000	51.827	90.000	51.827


G1 (Lower Spring Index) vs Drop Height
K=.0474 INCH
R=.0575 INCH
AL=51.14 DEG.
G2=300 G's
X1=.0327 INCH
X2=.0654 INCH
X3=.0327 INCH
COEFFICIENT
OF FRICTION
(μ)
μ=.6
μ=.3
μ=0
Drop Height (ft)
G1 (G's necessary to cause the pin to move from
the safe position: the start of compression)
120
110
100
90
80
70
60
50
40
30
20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300

```
*********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= 0 FRICTION
 GI= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 AI= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
*********************************************
```

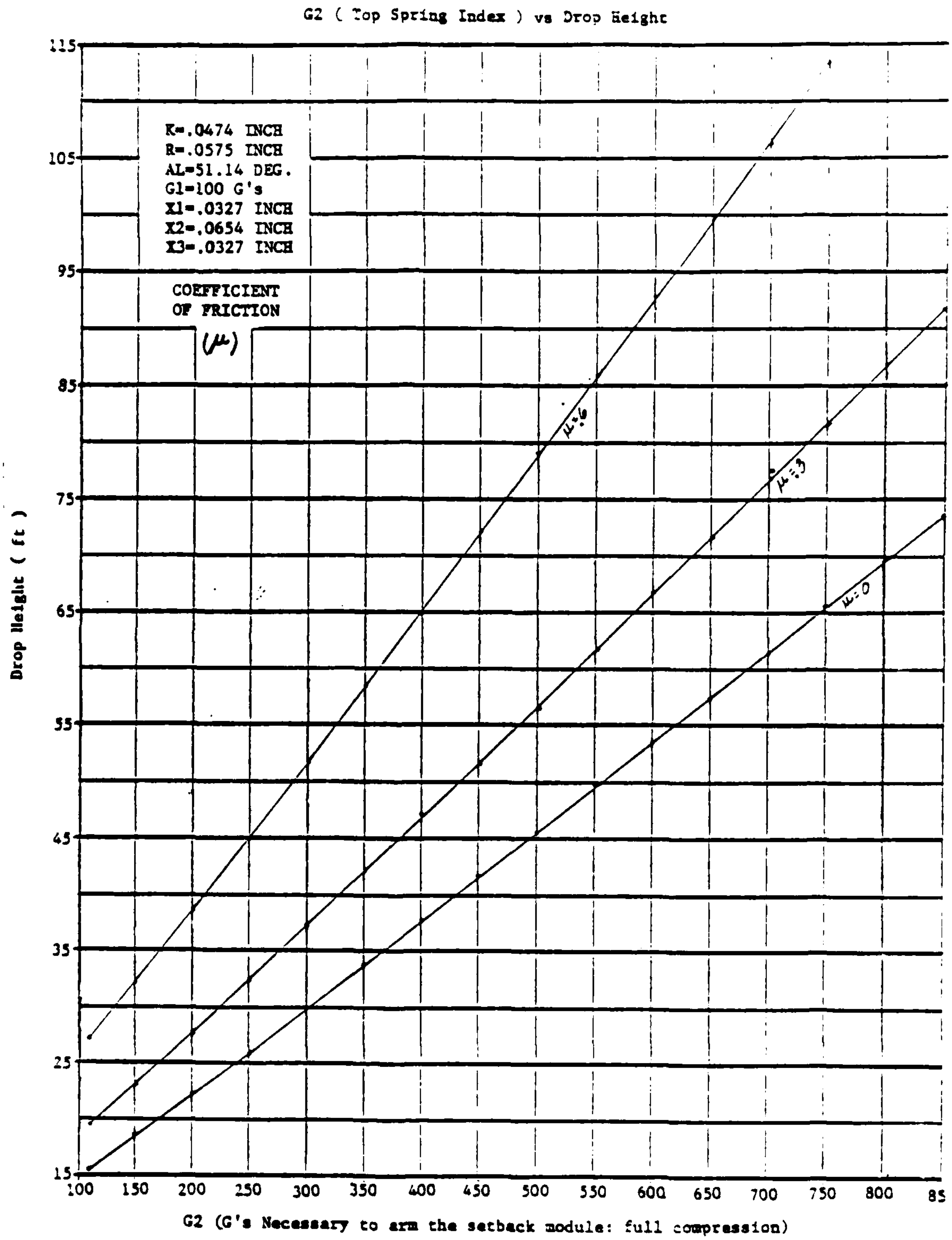
(GI) (G'S)	DROP HEIGHT (FT)
0.000	23.976
10.000	24.519
20.000	25.075
30.000	25.643
40.000	26.226
50.000	26.821
60.000	27.430
70.000	28.052
80.000	28.687
90.000	29.335
100.000	29.996
110.000	30.669
120.000	31.355
130.000	32.053
140.000	32.762
150.000	33.482
160.000	34.213
170.000	34.954
180.000	35.704
190.000	36.464
200.000	37.232
210.000	38.009
220.000	38.793
230.000	39.584
240.000	40.382
250.000	41.186
260.000	41.996
270.000	42.811
280.000	43.631
290.000	44.455

```
*********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= .3 FRICTION
 GI= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 AI= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
*********************************************
```

(GI) (G'S)	DROP HEIGHT (FT)
0.000	29.920
10.000	30.597
20.000	31.290
30.000	32.000
40.000	32.727
50.000	33.470
60.000	34.229
70.000	35.006
80.000	35.798
90.000	36.607
100.000	37.432
110.000	38.272
120.000	39.128
130.000	39.998
140.000	40.883
150.000	41.782
160.000	42.694
170.000	43.619
180.000	44.555
190.000	45.503
200.000	46.462
210.000	47.431
220.000	48.410
230.000	49.397
240.000	50.393
250.000	51.396
260.000	52.407
270.000	53.424
280.000	54.448
290.000	55.476

```
*********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= .6 FRICTION
 GI= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 AI= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
*********************************************
```

(GI) (G'S)	DROP HEIGHT (FT)
0.000	41.426
10.000	42.364
20.000	43.324
30.000	44.307
40.000	45.313
50.000	46.341
60.000	47.393
70.000	48.468
80.000	49.565
90.000	50.685
100.000	51.827
110.000	52.991
120.000	54.175
130.000	55.381
140.000	56.606
150.000	57.850
160.000	59.113
170.000	60.393
180.000	61.690
190.000	63.003
200.000	64.330
210.000	65.672
220.000	67.027
230.000	68.394
240.000	69.773
250.000	71.162
260.000	72.562
270.000	73.970
280.000	75.387
290.000	76.811


G2 (Top Spring Index) vs Drop Height
K=.0474 INCH
R=.0575 INCH
AL=51.14 DEG.
G1=100 G's
X1=.0327 INCH
X2=.0654 INCH
X3=.0327 INCH
COEFFICIENT
OF FRICTION
(μ)
μ=.6
μ=.3
μ=0
Drop Height (ft)
G2 (G's Necessary to arm the setback module: full compression)
115
105
95
85
75
65
55
45
35
25
15
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
85

****

K= .0474 INCH
R= .0575 INCH
AL= 51.14 DEG
MU= 0 FRICTION
G1= 100 G'S
G2= 300 G'S
X1= .0327 INCH
X2= .0654 INCH
X3= .0327 INCH
A1= 301 G'S
AF= 2000 G'S
I= 1 G'S

****

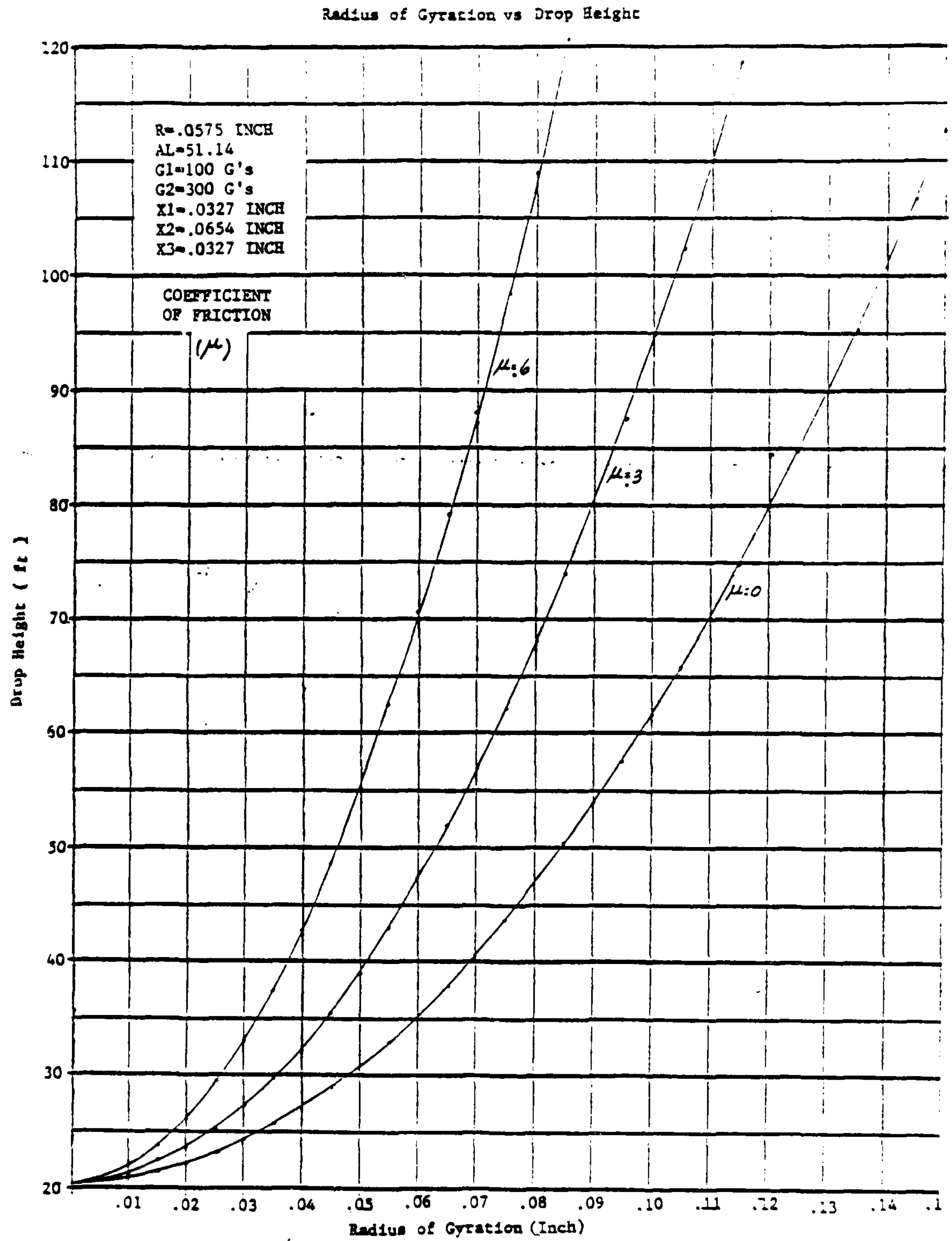
(G2) (G'S)	DROP HEIGHT (FT)
110.000	15.770
120.000	16.475
130.000	17.180
140.000	17.894
150.000	18.616
160.000	19.346
170.000	20.082
180.000	20.823
190.000	21.570
200.000	22.321
210.000	23.076
220.000	23.835
230.000	24.597
240.000	25.362
250.000	26.129
260.000	26.899
270.000	27.670
280.000	28.444
290.000	29.219
300.000	29.996
310.000	30.774
320.000	31.553
330.000	32.334
340.000	33.116
350.000	33.898
360.000	34.682
370.000	35.466
380.000	36.251
390.000	37.037
400.000	37.823
410.000	38.611
420.000	39.398
430.000	40.186
440.000	40.975
450.000	41.764
460.000	42.554
470.000	43.344
480.000	44.134
490.000	44.925
500.000	45.716
510.000	46.508
520.000	47.299
530.000	48.091
540.000	48.883
550.000	49.676
560.000	50.469
570.000	51.262
580.000	52.055
590.000	52.848
600.000	53.642
610.000	54.436
620.000	55.230
630.000	56.024
640.000	56.818
650.000	57.612
660.000	58.407
670.000	59.202
680.000	59.997
690.000	60.792
700.000	61.587
710.000	62.382
720.000	63.177
730.000	63.973
740.000	64.768
750.000	65.564
760.000	66.359
770.000	67.155
780.000	67.951
790.000	68.747
800.000	69.543
810.000	70.339
820.000	71.136
830.000	71.932
840.000	72.728
850.000	73.525
860.000	74.321
870.000	75.118
880.000	75.914
890.000	76.711
900.000	77.508

```
**********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= .3 FRICTION
 G1= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 A1= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
**********************************************
```

(G2) (G'S)	DROP HEIGHT (FT)
110.000	19.694
120.000	20.559
130.000	21.439
140.000	22.330
150.000	23.231
160.000	24.142
170.000	25.060
180.000	25.985
190.000	26.917
200.000	27.855
210.000	28.797
220.000	29.744
230.000	30.695
240.000	31.649
250.000	32.607
260.000	33.567
270.000	34.530
280.000	35.495
290.000	36.462
300.000	37.432
310.000	38.403
320.000	39.375
330.000	40.349
340.000	41.325
350.000	42.301
360.000	43.279
370.000	44.258
380.000	45.238
390.000	46.218
400.000	47.200
410.000	48.182
420.000	49.165
430.000	50.149
440.000	51.133
450.000	52.118
460.000	53.103
470.000	54.089
480.000	55.075
490.000	56.062
500.000	57.049
510.000	58.037
520.000	59.025
530.000	60.013
540.000	61.002
550.000	61.991
560.000	62.980
570.000	63.970
580.000	64.959
590.000	65.949
600.000	66.940
610.000	67.930
620.000	68.921
630.000	69.912
640.000	70.903
650.000	71.895
660.000	72.886
670.000	73.878
680.000	74.870
690.000	75.862
700.000	76.854
710.000	77.846
720.000	78.839
730.000	79.831
740.000	80.824
750.000	81.817
760.000	82.810
770.000	83.803
780.000	84.796
790.000	85.790
800.000	86.783
810.000	87.776
820.000	88.770
830.000	89.764
840.000	90.758
850.000	91.752
860.000	92.745
870.000	93.739
880.000	94.734
890.000	95.728
900.000	96.722

```
*********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= .6 FRICTION
 G1= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 A1= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
*********************************************
```

(G2) (G'S)	DROP HEIGHT (FT)
110.000	27.264
120.000	28.465
130.000	29.683
140.000	30.917
150.000	32.165
160.000	33.426
170.000	34.697
180.000	35.979
190.000	37.269
200.000	38.567
210.000	39.872
220.000	41.183
230.000	42.499
240.000	43.820
250.000	45.146
260.000	46.476
270.000	47.809
280.000	49.146
290.000	50.485
300.000	51.827
310.000	53.172
320.000	54.518
330.000	55.867
340.000	57.217
350.000	58.570
360.000	59.923
370.000	61.279
380.000	62.635
390.000	63.993
400.000	65.352
410.000	66.71[illegible]
420.000	68.073
430.000	69.435
440.000	70.797
450.000	72.161
460.000	73.525
470.000	74.890
480.000	76.256
490.000	77.622
500.000	78.989
510.000	80.356
520.000	81.724
530.000	83.093
540.000	84.462
550.000	85.831
560.000	87.200
570.000	88.571
580.000	89.941
590.000	91.312
600.000	92.683
610.000	94.055
620.000	95.426
630.000	96.798
640.000	98.171
650.000	99.544
660.000	100.916
670.000	102.290
680.000	103.663
690.000	105.036
700.000	106.410
710.000	107.784
720.000	109.158
730.000	110.533
740.000	111.907
750.000	113.282
760.000	114.657
770.000	116.032
780.000	117.407
790.000	118.782
800.000	120.158
810.000	121.533
820.000	122.909
830.000	124.285
840.000	125.661
850.000	127.037
860.000	128.413
870.000	129.790
880.000	131.166
890.000	132.542
900.000	133.919



Radius of Gyration vs Drop Height
R=.0575 INCH
AL=51.14
G1=100 G's
G2=300 G's
X1=.0327 INCH
X2=.0654 INCH
X3=.0327 INCH
COEFFICIENT
OF FRICTION
(μ)
μ:6
μ:3
μ:0
Drop Height (ft)
Radius of Gyration (Inch)

```
*********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= 0 FRICTION
 G1= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 AI= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
*********************************************
```

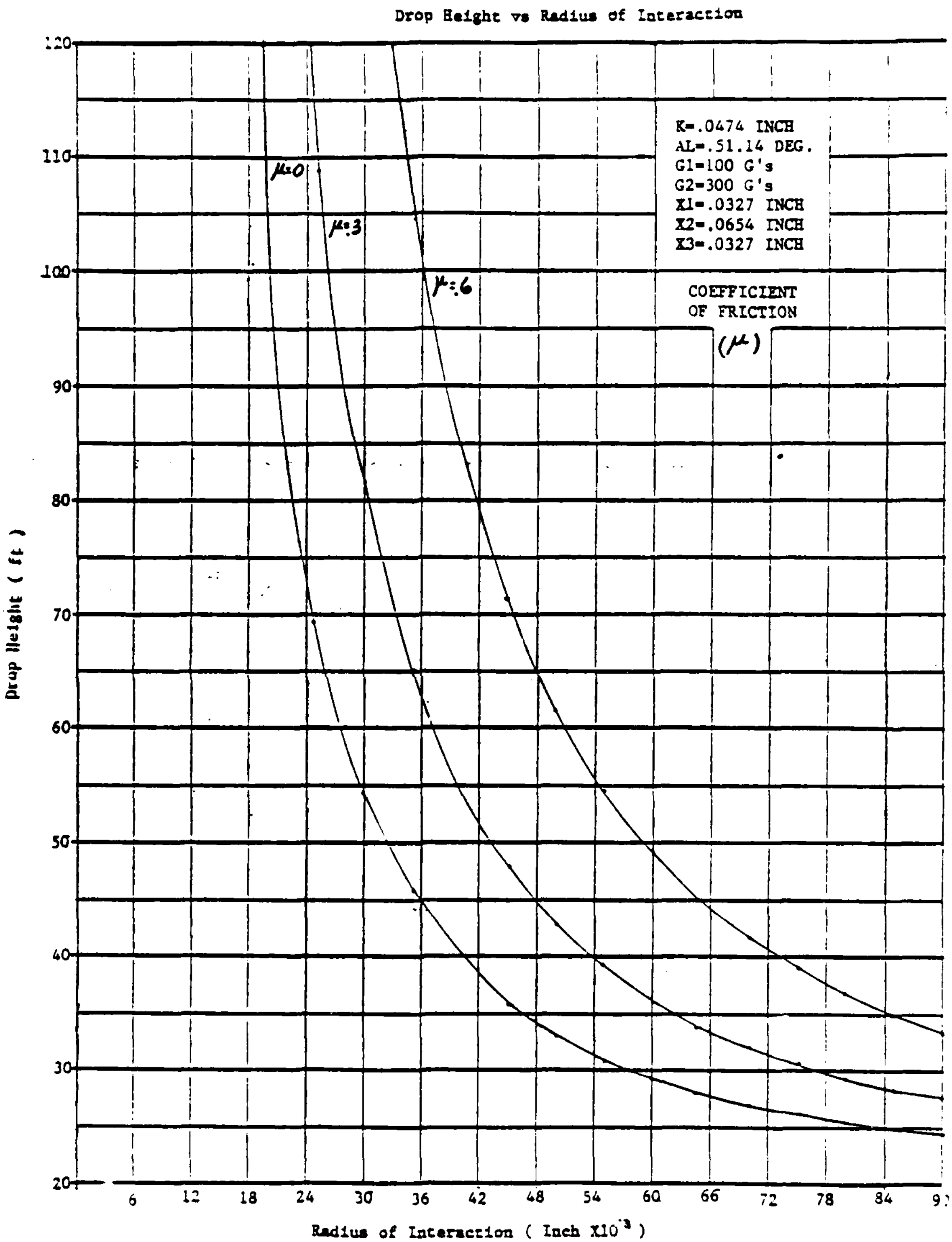
(R) (IN)	DROP HEIGHT (FT)
0.005	1235.200
0.010	324.409
0.015	155.744
0.020	96.712
0.025	69.389
0.030	54.546
0.035	45.597
0.040	39.788
0.045	35.806
0.050	32.957
0.055	30.850
0.060	29.247
0.065	27.999
0.070	27.009
0.075	26.211
0.080	25.557
0.085	25.015
0.090	24.561
0.095	24.177
0.100	23.849

```
*********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= .3 FRICTION
 G1= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 AI= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
*********************************************
```

(R) (IN)	DROP HEIGHT (FT)
0.005	2218.400
0.010	570.259
0.015	265.012
0.020	158.175
0.025	108.725
0.030	81.863
0.035	65.666
0.040	55.154
0.045	47.946
0.050	42.791
0.055	38.977
0.060	36.076
0.065	33.818
0.070	32.027
0.075	30.581
0.080	29.398
0.085	28.418
0.090	27.597
0.095	26.901
0.100	26.308

```
*********************************************
  K= .0474 INCH
  R= .0575 INCH
 AL= 51.14 DEG
 MU= .6 FRICTION
 G1= 100 G'S
 G2= 300 G'S
 X1= .0327 INCH
 X2= .0654 INCH
 X3= .0327 INCH
 AI= 301 G'S
 AF= 2000 G'S
  I= 1 G'S
*********************************************
```

(R) (IN)	DROP HEIGHT (FT)
0.005	4122.380
0.010	1046.210
0.015	476.543
0.020	277.161
0.025	184.876
0.030	134.746
0.035	104.519
0.040	84.900
0.045	71.450
0.050	61.829
0.055	54.711
0.060	49.296
0.065	45.083
0.070	41.740
0.075	39.043
0.080	36.835
0.085	35.006
0.090	33.472
0.095	32.175
0.100	31.067


Drop Height vs Radius of Interaction
K=.0474 INCH
AL=.51.14 DEG.
G1=100 G's
G2=300 G's
X1=.0327 INCH
X2=.0654 INCH
X3=.0327 INCH
COEFFICIENT
OF FRICTION
(μ)
μ=0
μ=.3
μ=.6
Drop Height (ft)
Radius of Interaction (Inch X10^-3)
120
110
100
90
80
70
60
50
40
30
20
6
12
18
24
30
36
42
48
54
60
66
72
78
84

```
*********************************************
 K= .0474 INCH
 R= .0575 INCH
AL= 51.14 DEG
MU= 0 FRICTION
G1= 100 G'S
G2= 300 G'S
X1= .0327 INCH
X2= .0654 INCH
X3= .0327 INCH
A1= 301 G'S
AF= 2000 G'S
 I= 1 G'S
*********************************************
```

(K) (IN)	DROP HEIGHT (FT)
0.005	20.916
0.010	21.222
0.015	21.733
0.020	22.448
0.025	23.368
0.030	24.492
0.035	25.820
0.040	27.353
0.045	29.089
0.050	31.031
0.055	33.176
0.060	35.526
0.065	38.081
0.070	40.840
0.075	43.803
0.080	46.970
0.085	50.342
0.090	53.918
0.095	57.698
0.100	61.683

```
*********************************************
 K= .0474 INCH
 R= .0575 INCH
AL= 51.14 DEG
MU= .3 FRICTION
G1= 100 G'S
G2= 300 G'S
X1= .0327 INCH
X2= .0654 INCH
X3= .0327 INCH
A1= 301 G'S
AF= 2000 G'S
 I= 1 G'S
*********************************************
```

(K) (IN)	DROP HEIGHT (FT)
0.005	20.998
0.010	21.553
0.015	22.478
0.020	23.772
0.025	25.436
0.030	27.470
0.035	29.874
0.040	32.648
0.045	35.791
0.050	39.305
0.055	43.188
0.060	47.441
0.065	52.064
0.070	57.057
0.075	62.419
0.080	68.152
0.085	74.254
0.090	80.726
0.095	87.568
0.100	94.779

```
*********************************************
 K= .0474 INCH
 R= .0575 INCH
AL= 51.14 DEG
MU= .6 FRICTION
G1= 100 G'S
G2= 300 G'S
X1= .0327 INCH
X2= .0654 INCH
X3= .0327 INCH
A1= 301 G'S
AF= 2000 G'S
 I= 1 G'S
*********************************************
```

(K) (IN)	DROP HEIGHT (FT)
0.005	21.158
0.010	22.194
0.015	23.919
0.020	26.335
0.025	29.441
0.030	33.237
0.035	37.723
0.040	42.899
0.045	48.766
0.050	55.323
0.055	62.570
0.060	70.507
0.065	79.134
0.070	88.452
0.075	98.459
0.080	109.157
0.085	120.545
0.090	132.624
0.095	145.392
0.100	158.851

APPENDIX G

ETCHING PROCEDURE

FOR HOUSING

M577 Modular Setback Pin

Etching procedure for housings - to reduce cam size

Process reduces housing OD from .1775" to .1764"

Bright Dip Solution ref: Metal Finishing Handbook 1981, Page 182

263g. Chromic Acid
23g. Sodium Sulphate
1000 ml. D.I. Water
room temperature

Zn. Cleaner

Patclin #357 Zinc Cleaner
45 g/1
150°F

Procedure:

1. Degrease in chlorothene; dry.
2. Agitate in bright dip for 60 seconds; rinse.
3. Remove smut in Zinc cleaner in ultrasonic cleaner, approx. 3 mins.
4. Rinse and dry.

APPENDIX H

M577 MODULAR SETBACK PIN

BALLISTIC TESTING SUMMARY

DG/"C"/KG

M577 MODULAR SETBACK PIN BALLISTIC TESTING SUMMARY

HAT LOT NUMBER	TOTAL FUZES TESTED	DATE SHIPPED	GUN & ZONE	FUZES FUNCTIONED	UNITS THAT COULD BE EVALUATED: TIMERS FUNCTIONED	UNITS THAT COULD BE EVALUATED: TRIGGERS FUNCTIONED
E022	15	21 May 80	105mm Z7	5/5	5/5	5/5
			155mm Z1 PD	5/5	-	5/5
			8-inch Z1	2/5	2/5	5/5
E028	32	15 July 80	8" Z1	20/24	20/24	24/24
			105mm Z8	8/8	8/8	8/8
E031	12	6 Oct. 80	155mm Z1	10/12	10/12	-
E030	20	7 Oct. 80	8-inch Z1	20/20	20/20	-
E044	36	10 Dec. 80	155mm Z1	16/18	16/18	-
E045			155mm Z1	11/18	11/18	-
E051	30	14 May 81	155mm Z1	30/30	30/30	-
E056	102	Sept. 81	155mm Z8	15/20	15/15	15/15
			105mm Z7	7/10	7/7	7/7
			8-inch Z1	6/10	8/8	10/10
		(Rough Handling)	105mm Z7	24/32	24/24	24/24
		(Recovery)	155mm Z8	11/15	15/15	14/15
		(Recovery)	155mm Z1	8/15	13/15	14/15
E107 *	106	May 83	155mm Z8	20/20	20/20	20/20
			8-inch Z1	20/20	20/20	20/20
			8-inch Z½	15/15	15/15	15/15
			4.2-inch incr7	15/15	15/15	15/15
		(Rough Handling)	105mm Z7	13/16	13/13	16/16
E113 *	15	May 83	155mm Z1 (Recovery)	15/15	15/15	15/15

* For more complete information on this test see Page

APPENDIX G

ENGINEERING TEST

SUPP #4-TPR-2594 (YPG)*

WEAPON	ZONE	TEMP	SET TIME	REL	$\bar{X}$	σ	LPD
(2) 155MM,M198	8(M203)	+145°F	105.0	20/20	105.312	.335	-
(1) 155MM,M198	8(M203)	+145°F	105.0	20/20	105.128	.299	-
(1) 8 INCH,M2A1	1	-35°F	25.0	20/20	24.870	.055	0
(2) 8 INCH,M2A1	1	-35°F	25.0	20/20	24.880	.057	0
(1) 8 INCH,M2A1	1/2	+70°F	15.0	13/15	14.947	.066	0
(2) 8 INCH,M2A1	1/2	+70°F	15.0	15/15	14.943	.059	0
(1) 4.2 INCH,M30	7 INCR	+70°F	13.0	15/15	13.064	.071	-
(2) 4.2 INCH,M30	7 INCR	+70°F	13.0	15/15	13.029	.059	-
(3) 105MM,M103	7	+70°F	50.0	13/16	50.054	.073	0
(1) 155MM,M1	1	+70°F	PD/FUNCT	20/20	-	-	-
(2) 155MM,M1	1	+70°F	PD/FUNCT	20/20	-	-	-
(4) 155MM,M198	1	+70°F	15.0	15/15	-	-	-

*LEGEND: (1) HAMILTON LOT 83D000E108 - CONTROL RDS.

(2) HAMILTON LOT 83D000E107 - RDS. ASSEMBLED W/PIN ASSEMBLED IN TIMER AND TRIGGER (ZIG-ZAG).

(3) HAMILTON LOT 83D000E107 - SEQ. ROUGH HANDLED - 8RDS @-35°F, 8 RDS @+145°F.

(4) HAMILTON LOT 83D000E113 - (15) TEST RDS - 5 EA RECOVERY VEHICLES WERE FIRED.

13,14 MAY 1983

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